Université de Montréal

The Relationship Between Product Design and Business Models in the Context of Sustainability

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Résumé

Dans les sphères du développement durable, des modèles d'affaires et du design de produit, certains leviers rendent le croisement de ces trois sphères de plus en plus pertinent. Au croisement de ces trois sphères se trouve une opportunité de comprendre les relations existantes entre le design de produit et les modèles d'affaires afin d'aider les décideurs à développer des solutions davantage durables.

L'approche méthodologique de cette recherche utilise un système complexe et est basée sur un paradigme pragmatique. En vue de répondre à la question « Dans quelle mesure des modèles d'affaires et le design de produit sont liés dans un contexte de développement durable? », cette recherche a soigneusement analysé trois cas: *Better Place*, une compagnie californienne ayant développé une infrastructure permettant le chargement des voitures électriques; *Interface Inc.*, un manufacturier mondial de tuiles de tapis commerciales établi à Atlanta; et *Métacycle*, un concept d'entreprise développé par une équipe de chercheurs en design à Montréal. Chaque cas a été analysé en corrélant des aspects du design de produit à des éléments de leur modèle d'affaires.

Les résultats montrent que dans le contexte du développement durable, le design de produit et les modèles d'affaires sont interdépendants. Les résultats peuvent être résumés en six points: il existe des relations applicables universellement; les innovations de design substantielles jouent un rôle important dans le développement durable; la « durabilité » peut être une qualité émergente d'un modèle d'affaires; les partenariats peuvent être vitaux pour l'intégration des systèmes; un modèle de services a des bénéfices et des limitations considérables; le design peut agir comme levier à l'utilisation d'énergies renouvelables. Pratiquer simultanément l'innovation du modèle d'affaires et du produit peut apporter une valeur ajoutée, susciter des opportunités et augmenter l'efficience sur plusieurs facettes. Toutefois, les risques et les coûts de tels procédés sont souvent très élevés.

En aidant à comprendre et définir comment les trois sphères mentionnées plus tôt sont interdépendantes, cette recherche pourrait idéalement inspirer des recherches supplémentaires sur le sujet. L'application par des organisations de la méthodologie et des apprentissages résultant de cette recherche peut permettre à d'autres d'utiliser le croisement entre l'innovation de produit et l'innovation du modèle d'affaires afin de résoudre des enjeux sociaux et environnementaux complexes.

Mots-clés : *Développement durable; design de produit; modèles d'affaires; innovation, stratégie.*

Abstract

Certain drivers in the fields of sustainability, business models, and product design are making the intersection between these three fields increasingly relevant. At this intersection is the opportunity to understand the relationships that exist between product design and business models to help decision makers develop more sustainable solutions.

The methodology of this research uses a complex systems approach and is grounded in a pragmatist paradigm. To answer the question "In the context of sustainability, in what way are business models and product design related?", this research has carefully analysed three cases: *Better Place*, a US based company that has developed a charging infrastructure for electric cars; *Interface Inc.*, a global commercial carpet tile manufacturer based in Atlanta, Georgia; and *Metacycle*, a company concept developed by a team of design researchers in Montréal, Québec. Each case is analysed by correlating aspects of product design to elements of the business model and assessing how these relationships affect the sustainability of the company.

The results show that product design, business models, and sustainability are inextricably connected. The results can be summarized in six key insights: there *are* universally applicable relationships; discontinuous design innovation can play a vital role in sustainability; sustainability is an emergent quality of a business model; key partnerships support systems level integration; a service revenue model has significant benefits and limitations; design innovation can help drive the shift to renewable energy. Conducting business model innovation and product innovation simultaneously can have large payouts in the form of creating new value, uncovering opportunities, and increasing efficiencies many fold, however the risks and costs of such a process are often very high.

Applying the methodology and lessons of this research to one's own organization could help to uncover new opportunities for innovation and help create more sustainable solutions. This research, by helping to understand and define how these areas are inextricably related and interdependent, will hopefully inspire further research on the subject and help others to use the intersection between product design and business model innovation to solve complex problems, be they social, environmental or otherwise.

Keywords: *Sustainability, Product Design, Business Models, Innovation, Strategy*

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Dedication

This work is dedicated to
tomorrow's child…

Tomorrow's Child

Without a name; an unseen face
and knowing not your time nor place
Tomorrow's Child, though yet unborn,
I met you first last Tuesday morn.

A wise friend introduced us two,
and through his sobering point of view
I saw a day that you would see;
a day for you, but not for me.

Knowing you has changed my thinking,
for I never had an inkling
That perhaps the things I do
might someday, somehow, threaten you.

Tomorrow's Child, my daughter-son
I'm afraid I've just begun
To think of you and of your good,
Though always having known I should.

Begin I will to weigh the cost
of what I squander; what is lost
If ever I forget that you
will someday come to live here too.

- Glenn Thomas (1996)

Acknowledgements

Behind the name published on the cover of this work is a broad network of people who have provided unwavering support. For that, I can never be grateful enough. I would like to briefly mention Philippe Lalande, my research director, for initially planting the seed that I should pursue a graduate degree and then for his steadfast guidance, wisdom and humour; Simone Zriel, my academic advisor, for her patience and serenity; Alexandre Joyce, for his friendship first and foremost, for his constant encouragement, and for the countless ways he has contributed his time and insight into this research; Carmela Cucuzzella, for taking the time to teach me everything she knows about being a dedicated graduate student, for helping me develop my ideas, and for always believing in my work; Tomás Dorta, for going above-and-beyond his responsibilities as a professor and for giving me the confidence to be bold in the scope and purpose of my projects; Fabienne Munch, for empowering me to work on challenging assignments and for making me feel at home during my time working at Herman Miller in Holland, Michigan; Anabelle Martin, for always being there to make me smile when I needed a break from my research; and my mother Diana, my father Charles, and my sister Lindsay for their unconditional love and support. The rest of my support includes far too many people to name here, so unfortunately, they will have to remain anonymous for now. I could never have done this alone, nor would I have ever wanted to try.

To all of you, sincerely, thank you.

Chapter 1. Introduction

On the highest level, the problem that this thesis addresses is the overwhelming negative ecological impacts that are associated with the global industrial system. To meet the wants and needs of the world's population, businesses all over the world plunder the earth's natural resources, contaminate the soil, poison the waterways and defile the air quality. Many scientists agree that ultimately, the environmental degradation caused by the industrial system is a design problem. All the products, services, and processes used to meet society's needs have been designed by somebody and more often than not, lead to environmental consequences that fall well beyond the scope of the project. When there are only a few companies in the world that produce environmental impacts, they go unnoticed. When the actions of millions of companies causing environmental impacts are aggregated, the consequences are dire.

Meanwhile, the economy is undergoing another shift. In his book, *A Whole New Mind: Moving from the Information Age to the Conceptual Age*, Daniel Pink makes the case that our society and our economy is in the midst of a massive shift from what can be described as an Information Age to a Conceptual Age (Pink, 2005). The Information Age was characterized by logical, linear, computer-like capabilities often associated with left-brain thinking. Abilities associated with lawyers, programmers and MBA's were highly valued by business. Pink argues, however, that the huge social and economic forces that he calls Abundance, Asia and Automation are shifting the Information Age paradigm (see **Appendix 1:** The Role of Abundance, Asia and Automation in Shifting the Information Age Paradigm). In the conceptual age, the role of creative thinking will permeate all areas of the economy and the blurring of the lines between design and business has already begun. This research also addresses this shift to a more integrated landscape where designers and business leaders are increasingly being pushed to creatively solve problems together.

The winter 2008 issue of the MIT journal *Design Issues*, entitled "Design and Organizational Change", looks at the close relationship that exists between design and organizations. The influences that design and organizations have on each other are far reaching considering that most design is either done by organizations or done for organizations (Brown et al., 2008). The capacity for environmentally conscious design to precipitate organizational change is even greater, however, considering the first step in designing a sustainable product or service is to question the way a business responds to the needs of its customers (Brezet & Hemel, 1997). Many environmental and business leaders are calling for new sustainable business models, and understanding how product design and business models could work together to create more sustainable solutions is at the core of this research.

To answer the question "In what ways are product design and business models related in organizations where sustainability is a top priority?", this research carefully analyses three cases: Better Place, a US based company that has developed a charging infrastructure for electric cars; Interface Inc., a global commercial carpet tile manufacturer based in Atlanta, Georgia; and Metacycle, a company concept developed by a team of design researchers in Montréal, Québec. Each case is analysed by correlating elements of product design to elements of the business model and assessing how these elements are related and how they affect the sustainability of the company.

This research is grounded in a pragmatist paradigm, in other words, the focus is placed on using the best approach to answer the research question in a way that can create actionable outcomes. Helping organizations become more sustainable by understanding the relationships between product design, business models, and sustainability, is the primary purpose of this research. Furthermore, a complex systems approach has been instrumental in shaping the methodology used to answer the research question. This approach has helped to recognize that any business is a complex system composed of numerous interrelated elements, and understanding the relationships between these elements is paramount to understanding the system.

The following chapter outlines the context of the three overlapping fields of product design, business models, and sustainability, and the primary drivers in each field that are making the intersection of these three fields increasingly relevant. The details of the research problem are elucidated in Chapter 3, followed by an in-depth description of the research methodology in Chapter 4. Chapters 5 through 7 present the three case studies, the results of which are discussed in Chapter 8, along with future implications. Finally, Chapter 9 offers a general summary of the research.

Chapter 2. Context

The context that this research looks at consists of three areas: product design, business models, and sustainability (Figure 1). Numerous contextual factors have emerged throughout the evolution of these fields, particularly recently, making the intersection of these three fields increasingly relevant. In the field of sustainability, many sustainable development advocates recognize the limitations of focusing only on increasing efficiency in a paradigm of unlimited economic growth. As a result, they are calling for new business models based on sustainable principles. In the product design field, sustainable design strategies propose solutions based on needs, creating not only products but services or systems when necessary. Also, design firms are expanding their service offering to include research, strategy, and business innovation, using design methodologies to solve business problems. In the business model field, theory on defining and innovating business models is maturing with numerous theoretical frameworks advocating a needs-based approach. Further, business leaders are recognising the usefulness of design methodologies and are applying them to their roles as business decision makers. Lastly, the maturing of the internet into an underlying fabric of our lives, the digitization of products, social media, manufacturing and material technologies all contribute to new possibilities for transformative, innovative business models. These three areas, and the three intersections between them, represent the context of this research and are highlighted by the grey background in Figure 1. These six areas will be discussed in sections 2.1 through 2.6 of this chapter. The area at the center of the model, where all three areas overlap, represents the specific problem area of this research, which will be defined in the following chapter.

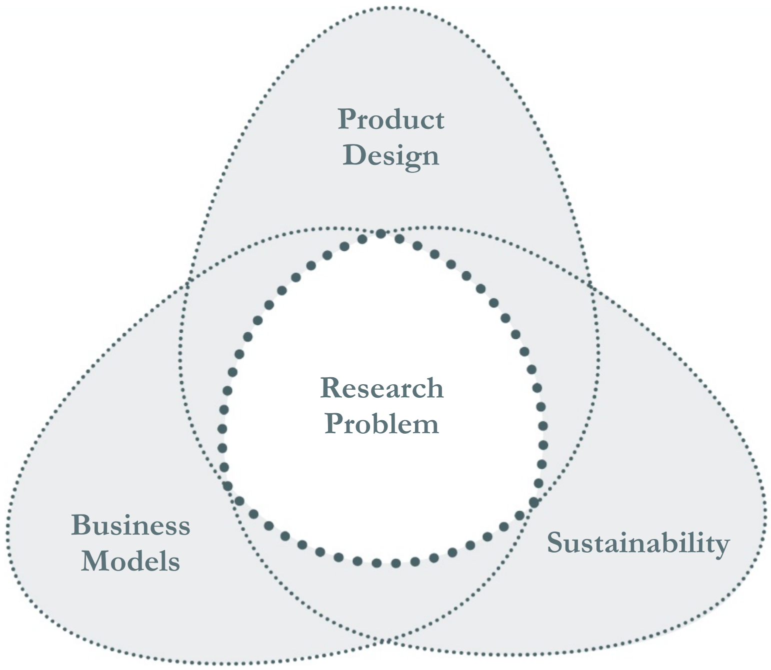


Figure 1: Research Model with Context Highlighted by Grey Area

2.1 Product Design

2.1.1 Design Background

Design has existed as long as human civilization, and as an activity it has a substantial amount of tradition (Heufler, 2009). It is easy to imagine the earliest humans shaping materials into utilitarian objects considering that today even primates use found objects as tools for various tasks. As human civilization became progressively more complex, design as an activity and as a discipline has been fundamental. After all, people were designing objects and buildings long before design became formalized in education or in the professional world.

Although design *has* become formalized, defining its nature seems to be quite hard. Comparing design with the sciences, Herbert Simon is of the position that the natural sciences are concerned with how things are, while design, on the other hand, is concerned with how things ought to be (Simon, 1969). Evidently, "design plays a key role in architecture, interior design, industrial design, engineering, graphic design, urban design, information system design, interaction design, and fashion design" (Margolin, 1989, p. 4). But what exactly that role is can be elusive. Some design scholars define design in extremely broad terms, broad enough to lead to the belief that everyone is a designer. For example, Simon defines design as the changing of existing conditions into preferred ones (Simon, 1969), and Victor Papanek defines the design process as "the planning and patterning of any act toward a desired, foreseeable end" (Papanek, 1971, p. 17). As such, some scholars on the subject insist that all people are designers, in that everyone engages in planning activities with very specific intended outcomes (Norman, 2005; Papanek, 1971). Scholars of design have traditionally viewed design in these very broad terms, but some have often protected designers' perceived contribution to society by limiting the definition of design activities to formalized graphic design, industrial design, interior design, architecture, landscape architecture, urbanism, fashion design and interaction design. Bill Buxton, former lead designer of Buxton Design and current principle researcher for Microsoft says that "we are no more all designers because we choose the colours of our walls, and furniture arrangements, than we are all mathematicians because we can count change when we go to the corner store" (Buxton, 2008, p. 53). Although everyone may engage in design activities, designers by profession are trained and practised in the processes, methodologies and ways of thinking associated with the discipline of design.

Richard Buchanan takes a bit of a different approach in that he believes any definition of design is too restrictive. He warns, "No single definition of design or branches of professionalized practice such as industrial or graphic design adequately covers the diversity of idea and methods gathered together under the label" (Buchanan, 1992, p. 5). To help understand design as an activity, Buchanan prefers to look at the myriad ways that design affects contemporary life by both professional designers and others who may not even consider themselves designers. Buchanan identifies four orders of design: communication, construction, strategic planning and systemic integration (see Appendix 2: Buchanan's Four Orders of Design). In their most simple terms, these areas of design can be thought of as media, objects, organizations and environments (Buchanan, 1992). The activities of design that this research focuses on is Buchanan's second and third area of design, the design of objects and organizations.

2.1.2 Product Design: An Activity of Industrial Design

Industrial design as a discipline began as a response to the industrial revolution and its associated processes and manufacturing methods. In an effort to integrate traditional crafts with mass production, industrial design was born to help manage the material understanding, form-giving and usability skills of the craftsman with a deep understanding of industrial manufacturing processes. In this sense, industrial design was initially concerned solely with the design of material objects. Over the years this perspective on industrial design has evolved and continues to evolve. Historically, design has been considered as a downstream step in the development process, where the designer, who has played no earlier role in the project, is asked to "come along and put a beautiful wrapper on the idea" (T. Brown, 2008, p. 86). But as the field has evolved, it's objectives are no longer just physical products, they are processes, services, technology enhanced interactions, entertainments and ways of communicating and collaborating (T. Brown, 2008). As industrial designers' outputs have begun to include the design of services and systems as well, the discipline has been expanding its definition to include these deliverables. The Industrial Designers Society of America (IDSA) currently defines Industrial Design (ID) as: "the professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of both user and manufacture." (IDSA, 2011). Some designers are weary of letting the definition of ID get too broad. Gadi Amit, owner and principle designer of New Deal Design, a self-professed "form-giver" (G. Amit, 2011b), warns that we should not forget the discipline of industrial design's roots:

> But let's not forget about the 'Industrial' bit. The toughest part of my job is to get young designers to recognize the significance of the industrial processes to their work. (…) In many schools, there's not much Industrial left in Industrial Design education. (…) Our fragile profession might do well to stand on the two legs it was born with: *Design* that is *Industrial*. (G. Amit, 2011a)

This thesis focuses on product design, the design of industrially produced objects. But as the relationship between product design, sustainability, and business models is further explored, the ability for designers to have a deep understanding of the complex systems in which products exist, and the ability to apply their skills to innovating those systems is paramount. One of the main reasons that industrial designers started doing service and system design projects in the first place, is due to the industrial designer's processes and way of thinking that have proved effective in the design of these other deliverables. The design process and some design methodologies are described in the following section.

2.1.3 The Design Processes

A designer's sequence of activities is called a design process (Simon, 1969). Despite the diversity of models of the design process, there are numerous common characteristics. Primarily, the design process can be considered to have three general spaces with vague, overlapping edges. The first space includes such activities as problem definition, research, strategy, and inspiration. The second space is about exploring options through brainstorming, ideation, sketching, and testing ideas. The third space is about execution and consists of such activities as detailed design development, communication, and creating deliverables. Tim Brown refers to these three spaces as inspiration, ideation and implementation (T. Brown, 2008). A second common theme is that generally the design process moves from the very broad to the very specific as it deals with problems that can have infinite possible solutions. Design problems are wicked problems in that they have no single correct solution, only good solutions and bad solutions (Buchanan, 1992). The last defining aspect to the design process is that it is iterative. As wicked problems have no clearly defined finished point (Buchanan, 1992), such is the nature of each stage of the design process. As a team moves forward in a project, no stage is entirely complete as new information is revealed on the nature of the work performed in the current and previous stages.

The design process is a unique creative problem solving process (see Appendix 3: Details of the Design Process). Very different from the scientific method, it is commonly used to solve wicked problems that have no single correct solution the way, for example, an algebra problem does. This process is starting to be thought of as having enormous value, even outside the field of the traditional design project. This notion will be discussed in the following section.

2.1.4 The Widening Scope of Design

As described above, industrial designers design products, services, and systems. But the ways a designer thinks and acts are perceived as valuable to not only design, but to business in a larger sense. Some have started looking into how design can play a role in shaping business strategy and organizational behaviour. In the winter 2008 edition of *Design Issues*, entitled "Design and Organizational Change", the introduction notes:

> That designers work for or with organizations is a familiar concept. That design can have an impact upon organizations and that design thinking can shape organizational behavior in productive ways is less well established within the literature devoted to design and design practice. (B. Brown, Buchanan, Doordan, & Margolin, 2008, p. 1)

In June 2004, the Stern School of Business at New York University held a conference on the subject of "Organization Design" which had the purpose of developing a scientific base for organization design, broadly defined as explicit efforts to improve organizations. This conference followed the "Managing as Designing" conference held in 2002 at the Weatherhead School of Management at Case Western Reserve University. These two conferences were part of the growing trend to study the role of design, often under the term "innovation", and its value to management and organizational change. In fact, since the 1990s, the perceived correlation between design and innovation has led a small but growing number of designers and design consultancies to become competitive with management consulting firms in certain areas of work (Buchanan, 2008). Organizations who are looking for an advantage in the increasingly competitive and creative business environment often demand innovation, a phenomenon thought of as the fruit of design competencies, processes and methodologies.

Considering that the demand for innovation is key to the widening of the scope of many design firms, a clear understanding of innovation is important. Saul Kaplan, founder of the Business Innovation Factory, a non-profit organization that looks to create systems level change in such areas as healthcare, education and energy, defines innovation as simply a better way to offer value. In a *Design Issues* article linking design with innovation, Barry Wyant helps define innovation saying that innovation is a new thing that can take on the form of a product, behaviour, system, process, organization, or business model (Wylant, 2008). He also describes how an early writer on innovation, Joseph Schumpeter, makes the distinction between innovation and invention by noting that there is an element of successful implementation and adoption in innovation. Combining these three aspects, innovation can be understood as anything of value that is both new, better, and has been implemented successfully. Wylant also adds that innovation is often thought of as falling into three categories: continuous innovation, where the innovation is an incremental improvement over what already exists; dynamically continuous innovation, where the innovation is a dramatic improvement over what already exists; and discontinuous or disruptive innovation, where a completely new technology or infrastructure leads to completely new uses and functionalities (Wylant, 2008). In the ultra-competitive landscape that most companies operate in today, innovation is vital to competition and differentiation.

As organizations are seeking to innovate in all areas of their organizations, design firms are expanding their offering even beyond product, service and system design to include all forms of business innovation as well as consulting in management and strategy. Jea Hoo Na and John Boult of Brunnel University did an extensive study on the evolution of numerous top North American and European design firms that began as entirely product design focused firms. Their findings are that more and more product design consultancies are diversifying from narrow original specialties into such disciplines as branding, business innovation, strategy and future foresight. Their product design heritage and the ways that they have been able to use that core skill is a fundamental reason they have emerged into the company they are today (Na & Bolt, 2010). In 2008, the Palo Alto based IDEO told Businessweek writer Bruce Nussbaum that 80% of their revenue comes from delivering a strategy to their client rather than a traditional design deliverable, while other top US design firms such as Continuum, Smart, and Ziba Design reported that percentage to be closer to 50% (Nussbaum, 2008).

One of the key reasons that designers are so well positioned for innovation and strategy is that they have a human centric approach. Since they are often thought of as bridging the gap between technology and users, through such aptitudes as user-interface design and ergonomics, designers thoroughly understand human factors. Designers are the ones creating the form factors of products and services. By directly interacting with end users, they have made it their business to see the world through the eyes of others. Much of the first space of the design process is about getting a deep understanding of the user, which leads to a better job of satisfying their needs. Satisfying needs is simply the most reliable source of long-term profitability and sustainable growth (T. Brown, 2009).

2.2 Business Models

2.2.1 The Increasing Importance of Business Models

Business model theory is a relatively new area of research and there are many reasons why business model theory is quickly gaining clout in business and innovation circles. The popularity of business model discussion grew significantly during the "dotcom" boom of the

1990's, when the technology of the internet was creating new opportunities for businesses (Rappa, 2001; Turban et al, 2002; from Hager, 2006). More specifically, the arrival of the internet "cut out middle men, opened self-service paths for consumers and allowed for more personalized products and services" (Franklin, 2005, p. 9). The first dotcom boom happened almost fifteen years ago, yet another online revolution is happening today. The internet is fast becoming an underlying fabric of people's lives fuelled by 24-hour-a-day connectivity. Such mega trends as ubiquitous mobile devices, GPS, the digitization of products, and social-media enabled collaborative consumption, combined with innovations in transportation, energy, materials, and manufacturing are opening the door for radical new ways to create value. These opportunities are leading to significant changes in the way businesses can operate, and the business model concept is helping business leaders make sense of the new landscape. Furthermore, due to globalization and information technology, organizations are trying to find ways to meet user's complex demands by shifting from the production of goods to the provision of knowledge-intensive systemic solutions (Morelli, 2002). In order to bring such solutions to market, businesses are increasingly looking to new business models.

According to the *IBM Global CEO Study 2006*, based on in-person interviews with more than 750 of the world's top CEOs and business leaders, 65% of respondents thought business model innovation would be the most important innovation of the future (Franklin, 2005). The report cites too many choices in the market as a primary driver for the importance of business model differentiation[1]. As the market is flooded with choices, it becomes more difficult to differentiate between products and services on a purely functional basis (Franklin, 2005). Also, the costs of bringing new products to market have risen tremendously and shorter product lives means that even great technologies can become commoditized before earning a satisfactory profit. As a result, companies are starting to focus on both business model innovation and product innovation to stay competitive (Chesborough, 2007).

2.2.2 Business Model Definition

The business model, as a concept, has been confusing to many because the term has lacked an agreed upon definition and is commonly used with different meanings in everyday business dialogue (Osterwalder, 2004). A common definition is that "a business model is a

[1] This point is referring to the same phenomena as the mega trend identified by Daniel Pink as "abundance".

method of doing business by which a company can generate revenue to sustain itself" (Rappa, 2001; Turban et al, 2002; from Hager, 2006). While this definition is not wrong per se, it is somewhat reductionist and is focused on the way a company generates revenue. People often think that a revenue model is interchangeable with a business model, but as we will see below, a revenue model, or profit formula, is only one piece of the broader business model (Johnson, Christensen, & Kagermann, 2008). Among those who view the business model in its full scope and identify some of the relevant components, three stand out: Saul Kaplan, Mark Johnson, and Alexander Osterwalder.

Saul Kaplan is the founder of the non-profit Business Innovation Network, and former Executive Counsellor to the Governor of Rhode Island on Economic Growth and Community Development. Kaplan defines a business model as a network of capabilities and a sustainable financial model to deliver value to target customers (Kaplan, 2009). The relationship between the operating model, the customer experience, and the financial model is represented in Kaplan's model below (Figure 2). Basically, operating costs (represented on the left) create a valuable experience (represented on the right), both affecting the financial model (underlying).

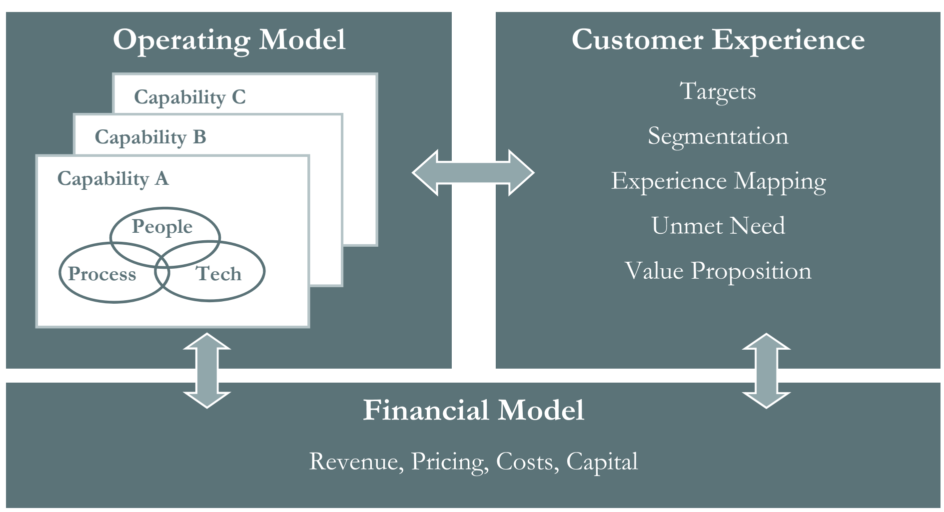


Figure 2: Saul Kaplan's Business Model (Redrafted from Kaplan, 2009)

Mark Johnson, chairman of the innovation and strategy-consulting firm Innosight, Clayton Christensen, professor of Business Administration at Harvard Business School and Henning Kagermann, the co-CEO of software giant SAP AG co-authored an article in the

Harvard Business Review called "Reinventing your Business Model" (2008). Johnson et al define a business model as an interlocking of four key elements that come together to create and deliver value. These four elements are a customer value proposition, a profit formula, key resources and key processes (Johnson et al., 2008). The most important element is the customer value proposition (CVP), which is a way to get an important job done for the customer essentially providing a valid solution to a pressing problem. The profit formula represents the financial factors that lead to successfully profiting on the CVP, such as details of money coming in from customers and going out for costs. Key resources are assets that are used to bring the CVP to the customer such as people, technology, facilities, brand etc. Lastly, key processes are the activities needed to bring the CVP to the customer such as manufacturing, selling, budgeting and planning (Johnson et al., 2008). Their model suggests that all key processes and resources, as well as the financial model, interact with each other to create a single output to the system, which is the customer value proposition (see Figure 3). The components common to most business model definitions are starting to emerge but as we will see below, Alex Osterwalder's model uses essentially the same components but includes a higher level of detail and refinement.

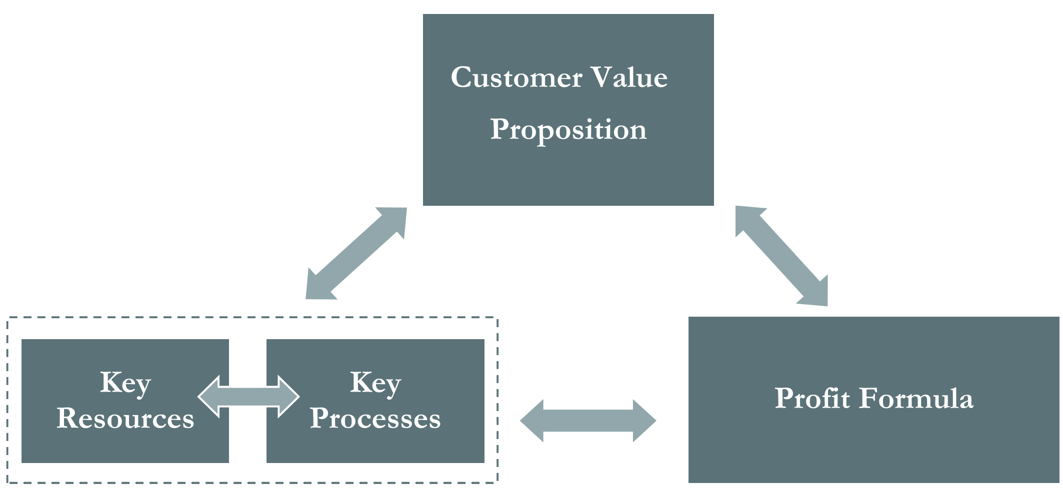


Figure 3: Elements of A Business Model (Adapted fromJohnson et al., 2008)

Having written his PhD on Business Model Innovation at the University of Lausanne, Switzerland, Alex Osterwalder implemented his business model innovation methodology in such companies as 3M, Ericsson, Capgemini, Deloitte, Telenor and many others. Osterwalder's book, co-authored with Yves Pigneur, *Business Model Generation: A Handbook for*

Visionaries, Game Changers, and Challengers (2009), presents the culmination of Osterwalder's many years of research on the topic of business models. Osterwalder's definition is as follows: "a business model describes the rational of how an organization creates, delivers and captures value" (Osterwalder & Pigneur, 2009, p. 14). To breakdown this description into its base components, Osterwalder & Pigneur use what they call the business model canvas (Figure 4).

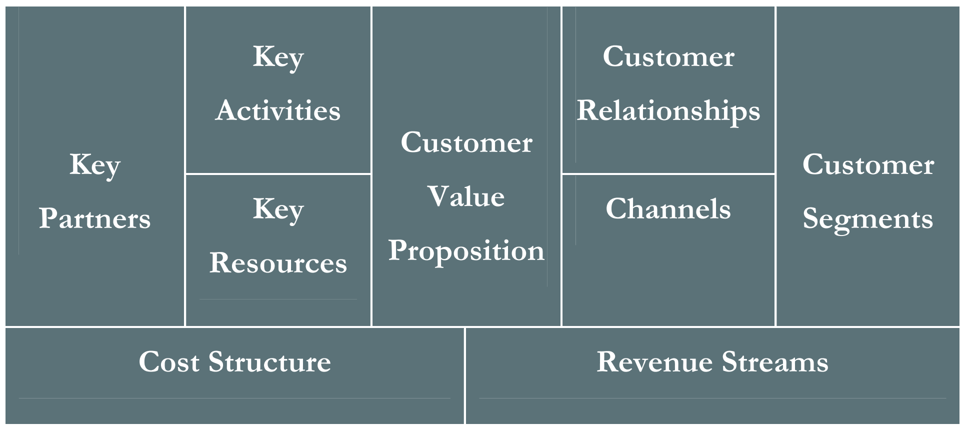


Figure 4: Business Model Canvas (Adapted from Osterwalder & Pigneur, 2009)

The business model canvas consists of nine building blocks, many of which overlap with the components of the aforementioned definitions. The nine building blocks are: Customer Value Proposition, Customer Segments, Channels, Customer Relationship, Key Activities, Key Resources, Key Partners, Cost Structure and Revenue Streams.

2.2.3 Business Model Ontology

Looking at the three business model models, or meta-models (Osterwalder, Pigneur, & Tucci, 2005) of Kaplan, Johnson et al, and Osterwalder & Pigneur, the definitions are quite similar and the models have many overlapping components. Kaplan and Osterwalder's models have in common the general positioning of the operations on the left, customer on the right and the financial model underlying all components. Johnson and Osterwalder's model have in common most components but a dissimilar positioning of those components relevant to each other. Since the Osterwalder model is the common denominator, and the fact that Osterwalder's model has been refined through extensive research and collaboration with 450 other participants, this thesis uses Osterwalder & Pigneur's model as a business model theoretical framework. The following paragraphs explain in detail the nine building blocks of the business model canvas.

Customer segments are the people or businesses an enterprise seeks to serve and create value for. Customer segments represent groups of customers that have different needs or behaviours and must be treated differently. It should be noted that customer segments do not always represent the end user who is normally the focus of many design projects.

The value proposition represents the products or services offered by an enterprise that create value for the customer segment. A strong value proposition solves a customer problem or satisfies a customer need. Kaplan, Johnson et al, and Osterwalder & Pigneur, all like to think of the value proposition in terms of helping a customer get an important job done.

Channels are the means to communicate with and reach a customer segment and to deliver the value proposition (Osterwalder & Pigneur, 2009). Essentially the communication, distribution and sales channels represent the parts of the company that interface directly with the customer. Five key phases of this customer interface are making the customer aware of the value proposition, helping the customer evaluate the value proposition, allowing the customer to purchase the offering, how the offering is delivered to the customer, and finally how the post-purchase customer support is provided.

Customer relationships represent the relationship an enterprise establishes with its customer segments. Customer relationships are very diverse and can be used to acquire new customers, retain existing customers, or boost sales (Osterwalder & Pigneur, 2009).

Revenue streams, or the revenue model as it is referred to by Johnson et al, represent how a company collects cash from its customers in exchange for delivering the value proposition. It can be thought of in terms of "price x volume" and can come in the form of asset sales, subscriptions, leasing, advertising and numerous other forms. Furthermore, in some models pricing is fixed while in others, such as negotiation or auctions, pricing is dynamic (Osterwalder & Pigneur, 2009).

Key Resources are the most important assets required to run the business model and the enterprise. These assets can come in the form of physical assets such as production facilities or vehicles, intellectual assets such as patents or brands, human assets such as designers or a sales force, or financial assets such as cash or lines of credit. These key assets don't always need to be owned by the enterprise - they can be leased in some cases, or even provided by partners.

Key activities are the actions an enterprise needs to do to run the business model successfully. Depending on an enterprise's business model, these actions can be very different. Clearly, for manufacturing firms, activities relating to production are perhaps the most key activities, whereas service businesses can have key activities such as research and providing legal advice in the case of a law agency. Some companies such as FedEx require continuous operational improvements and network management. In fact, Osterwalder and Pigneur suggest that most key activities fall into one of these three categories: production, problem solving or network management.

Key Partnerships represent the network of suppliers and partners that an enterprise uses to make its business model function. Generally, enterprises create partnerships to optimize and create economies of scale, reduce risk or uncertainty, or acquire resources and activities (Osterwalder & Pigneur, 2009).

The Cost Structure describes all the costs that an enterprise must incur to successfully run its business model. Generally, this part of the business model identifies the key costs associated with running the business model and managing them appropriately. It is also about understanding whether the model is more cost driven, where minimizing costs is the key driver, or if it is value driven, where creating the most valuable solutions is the key driver. It is also worth noting that costs generally are either fixed costs, in that they do not vary with output such as salaries and facility costs, and variable costs which are directly related to output such as raw material costs and transportation.

2.3 Sustainability

A complexity of interrelated ecological, social, cultural, economic, and psychological problems interact and converge in the current crisis of our unsustainable civilization (Wahl & Baxtor, 2008). Sustainability as a concept was first introduced in the field of ecology to describe "the capacity of a system to maintain a continuous flow of whatever each part of that system needs for a healthy exercise" (Madge, 1997, p. 51). Sustainability in terms of human development, or sustainable development, as it is known, is a concept that recognizes that human civilization is an integral part of the natural world and that nature must be preserved and perpetuated if the human community itself is to survive. Policymakers started to predict that the current industrial system may not be sustainable if infinite growth was coupled with limitless waste production, resource dependency, and energy use, which led to the formation of the formation of The World Commission on the Environment and Development (WCED) by the United Nations in 1983. In 1987, the WCED published the Brundtland Report, *Our Common Future*, which is recognized as one of the most influential environmental documents of the 20th century. The Brundtland report defined sustainable development as development that meets the needs of the present, without compromising the ability of future generations to meet their own needs (Brundtland & WCED, 1987).

One aspect that most agree upon, is that the WCED was justified when it set out a vision for sustainable development that called for the integration of economic, social and environmental decision-making. Since the Rio Earth Summit in 1992, there has been general consensus among politicians, non-governmental organizations, and business leaders alike, that when trying to create economic growth, ecological sustainability, and social welfare, neither element can be sustainable in the long run without equal consideration of the other two (Dyllick & Hockerts, 2002). John Elkington, founder of the leading global sustainable business consultancy, Sustain Ability, refers to the need for considering the economy, society and the environment as the triple bottom line of 21st century business (Elkington, 1998). Gendron and Revert, professors at the Université de Québec à Montréal, provide a thorough definition of sustainable development in that they define the roles of these three 'bottom lines'. In their definition of sustainable design, they suggest that to be sustainable, one must consider ecological integrity, economic factors, and social and individual development where ecological integrity is the condition, the economy is the means, and the social and individual development is both a goal and a means (Gendron & Revéret, 2000). With this understanding of sustainability, social and individual development is the goal. It is done through the economy and it must meet the condition of ecological integrity.

The Brundtland report introduced the definition of sustainable development and emphasized the "imbalance between the rich and poor parts of the world, arguing that those who are more affluent adopt lifestyles within the planet's means" (Madge, 1997, p. 51). It assured that economic growth is still possible as long as it is "green" growth which made some believe that the report was not radical enough in its position. The sustainability movement is not a single movement but is as varied as the citizens and communities that are affected by the issues it addresses (Van Der Ryn & Cowan, 2007). Despite this truth, however, there are two dominant approaches to sustainability that have emerged. David W. Orr, author of *The Nature of Design: Ecology, Culture and Human Intention* (2002) and *Ecological Literacy: Education and the Transition to a Postmodern World* (2006), calls these two approaches technological sustainability and ecological sustainability. Technological sustainability asserts that every problem has either a technological answer or a market solution. It believes that a "fundamental change in direction" (Van Der Ryn & Cowan, 2007, p. 20) is not necessary. This is essentially the outlook that the Brundtland report had advocated in 1987. Ecological sustainability, conversely, insists we need to completely rethink the processes that got us into these problems in the first place. It requires "limits to material wants, limits to the stress placed on the biosphere, and limits to hubris" (Van Der Ryn & Cowan, 2007, p. 22).

Herman Daly, an American ecological economist, current professor at the School of Public Policy of the University of Maryland, College Park and former Senior Economist in the Environment Department of the World Bank is concerned by the paradox of unlimited economic growth in the face of limited resources. Daly warns that "the global economy is now so large that society can no longer safely pretend it operates within a limitless ecosystem. Developing an economy that can be sustained within the finite biosphere requires new ways of thinking" (Daly, 2005, p. 100). Growth means to increase in size through the addition of material while development means to bring gradually to a better state. Expecting continuous economic growth is impossible when growth, by definition, requires increased use of finite natural resources. Likewise, Daly insists that sustainable development is only possible if development means development without growth. Such a scenario will require both radical increase in the efficiency of resource use and embracing the concept of sufficiency to help curb our demand for material goods (Vezzoli & Manzini, 2008).

2.4 Product Design and Sustainability

Sustainability is rapidly becoming an issue of critical importance for designers and society as a whole (Wahl & Baxtor, 2008). Victor Papanek was perhaps one of the first to place much of the responsibility of human sustainability and well-being on the shoulders of designers. Prior to the emergence of sustainable and ethical development on the international scale, renowned designer Victor Papanek was promoting his belief in ethical and ecological design theory and practice. First published in 1971, Papanek's *Design for the Real World: Human Ecology and Social Change* (1971) outlined his human-centered and ecological design principles.

Papanek was outspoken in his criticism of unsustainable business practices such as large multi-national companies who do not consider the waste of their packaging, or car companies who do not consider their gas-guzzling car designs.

Papanek was one of the pioneers of the ecodesign movement but ecologically conscious design has been through many stages since the seventies. Evenlyn Moeller coined the phrase "ecological functionalism" in 1982 and devised an ecological checklist for product designers and manufacturers. In the early nineties, the Design Research Society held a conference called The Greening of Design, which concentrated on how environmental factors affected new product development and business from a design management point of view. During this period, considering environmental criteria in the design process was referred to as green design. Eventually, the areas of green design, ethical business practices, and responsible consumerism overlapped to create a bigger picture that green designers would consider in the design process. This led the way to the term "ecological design" or ecodesign. Anne-Marie Willis, editor of *Design Philosophy Papers* notes that, "Ecodesign has the potential to be more than the reform of existing design, for if taken seriously, it can establish a new foundation for design that could bring economic and ecological needs into a new union" (As cited in Madge, 1997, p. 49). The terms ecodesign and "Design for the Environment" (DfE) eventually became synonymous, referring not only to the "adding in of environmental criteria to the design process but also the practice of adopting a systems approach either to the individual product or product system, or to industry as a whole" (Madge, 1997, p. 49). In his article "Dematerializing Consumption through Service Substitution is a Design Challenge", Chris Ryan reiterates that point saying that most ecodesign strategies focus on technical aspects of production concerned with reducing material and energy use, which reinforces the idea that design is typically concerned with material and technical functions (Ryan, 2000). As the boundaries of design for the environment or "industrial ecology" are pushed to include the entire production chain, consumption, and end-of-life treatment, design seems to be concerned with even more logistical and technical issues. However, due to factors such as economic growth, population increase, and rebound effects, reduction in environmental impacts simply get cancelled out by increased consumption. This is why Ryan suggests that "DfE and industrial ecology need to move toward defining and creating alternative systems of production and consumption that have significantly lower environmental impacts" (Ryan, 2000, p. 3). Inevitably, new systems of production and consumption that are based on sustainability will require organizations to adopt new business models that do not have conflicting incentives with sustainability.

Eventually, the term sustainable design began to replace ecodesign, as the boundaries of ecodesign continuously expanded. Comparing ecodesign to sustainable design, Emma Dewberry, a sustainable design researcher at Loughborough University and Phillip Goggin, co-ordinator of the ecodesign program at Goldsmiths College say:

> The concept of sustainable design, however, is much more complex and moves the interface of design outward to societal conditions, development and ethics. This suggests changes in design and the role of design, including an inevitable move from a product to a systems-based approach, from hardware to software, from ownership to service and will involve concepts such as dematerialization and a general shift from physiological to psychological needs. (As cited in Madge, 1997, p. 52)

The sustainable design movement has advocated that industry will have to change many of the fundamental principles that have governed the economic system for many years. In fact, numerous different entities have outlined their own ecodesign principles. In *The Sustainability Revolution: Portrait of a Paradigm Shift* (2005), Andres R. Edwards highlights the importance of having guiding principles and summarizes the leading initiatives within the sustainable design movement and their fundamental principles. By definition, "a principle is a guiding sense of the requirements and obligations of right conduct" (Edwards, 2005, p. 24). All of the sets of principles Edwards presents recognize the interdependence of design and nature. They all use as a basis the notion that nature can and should be used as a model for all industrial systems. The way that nature manages its energy and material flows, eliminating the concept of waste, and constantly regenerating itself in infinite cycles are ways that new forms of products, services and infrastructures can be redesigned to be sustainable.

The organization and classification of sustainable design strategies is a difficult task because there are so many. *EcoDesign: The Sourcebook* (2002), by Alastair Fuad-Luke, has 700 illustrated examples of environmentally sensible products and lists approximately 150 different strategies in an ecodesign strategies section toward the back of the book. Chapter 10 of *Sustainable Solutions: Developing Products and Services for the Future* (2001), by Martin Charter and Ursula Tishner also list many ecodesign strategies, but like *EcoDesign: The Sourcebook*, they lack explicit detail in their explanation of each strategy. *Ecodesign: A Promising Approach to Sustainable*

Production and Consumption (1997) by Han Brezet and Carlolin van Hemel, conversely, neatly organizes eight general sustainable design strategies, each with its own list of well explained sub-strategies (see Appendix 4: Sustainable Design Strategies and Sub Strategies). The eight sustainable design strategies are:

- **New Concept Development:** Addressed before any actual product design decisions are made. The focus is not on a physical product but on the function of a product system and the way it fulfills a need.

- **Selection of Low Impact Materials:** Very contingent on the life cycle of the product in that the appropriateness of materials is context relevant.

- **Reduction of Material Usage:** Suggests using the least amount of material possible by proposing lean yet strong product designs.

- **Optimization of Production Techniques:** Asserts that production techniques should minimize auxiliary materials and energy use.

- **Optimization of the Distribution System:** Ensures that the product is transported to the retailer from the factory in the most ecologically efficient manner possible.

- **Reducing Impact During Use:** Looks at reducing the consumables (such as energy, water, detergent, batteries etc.) associated with the use of a product.

- **Optimization of Initial Lifetime:** Has the goal of making the product useful for the longest possible time, through prolonging the technical, aesthetic and initial lifetimes of a product.

- **Optimization of End-of-Life System:** Requires proper waste-management and end-of-life treatment. Material cycles should be closed when possible or otherwise disposed of in the appropriate way.

Furthermore, the list of strategies is accompanied by an ecodesign checklist to which all strategies can be cross checked throughout a design project. Emma Dewberry's view of sustainable design as operating on a systems level and Brezet and Hemel's sustainable design strategies and sub-strategies form the basis of this thesis' definition of sustainable design.

2.5 Business Models and Sustainability

The same way policy makers in the early eighties began to question the sustainability of industrial development on a macroeconomic scale, so too did some business leaders on a microeconomic scale. They questioned whether continued environmental degradation would jeopardize the economic sustainability of their own enterprise. Other business leaders began to question the moral fabric of their enterprise, considering that many of their firm's activities were causing irreversible environmental damage such as ozone depletion and species extinction. The acknowledgment of warning signs may have been happening on both the macro and the micro levels simultaneously, but it was clear that, as the Brundtland report called for, there needed to be a large cooperation from industry. The report stressed that:

> Many essential human needs can be met only through goods and services provided by industry, and the shift to sustainable development must be powered by a continuing flow of wealth from industry. (Brundtland & WCED, 1987, p. 173)

In his book, *The Ecology of Commerce* (2010), Paul Hawken describes an entirely different economy that is inherently sustainable and restorative, but which still uses many of the market techniques of free enterprise that reward quickness and creativity. "Rather than a management problem", he maintains, "we have a design problem, a flaw that runs through all business" (Hawken, 2010, p. xiii). Hawken points out that creating a restorative economy means rethinking the fundamental purpose of business. Today, most people view business as simply a means of making money or a system of making and selling things. Hawken reminds his reader that:

> The promise of business is to increase the general well-being of humankind through service, a creative invention and ethical philosophy. Making money is, on its own terms, totally meaningless, an insufficient pursuit for the complex and decaying world we live in. (Hawken, 2010, p. 1)

According to Hawken, destructive behaviour is not inherent in the nature of the free-market system. It is a result of the design flaw and misuse of the current commercial system. Hawken presents a vision for the potential of commerce to be a force for positive change in the world. This ties in well with Gendron and Reveret's definition of sustainable development where they see ecological integrity as the condition, the economy as the means, and social and individual development as both the goal and the means.

In the article, *A roadmap for Natural Capitalism* (1999), Paul Hawken, Amory B. Lovins and L. Hunter Lovins outline a plan to make the transition to what they call "natural capitalism" and provide an array of compelling practical examples of how natural capitalism can benefit both business and the environment. At the heart of their model is the thesis that 90–95% reductions in material and energy are possible in developed nations without diminishing the quantity or quality of the services that people want. In fact, the holistic approach to solutions presented in this article suggest that people's needs will be met in even more fulfilling ways, because social factors must be considered hand in hand with environmental factors. Natural capitalism suggests four major shifts in business that can lead to the increases in efficiency stated above. These four shifts can be seen as the solutions to the design flaw of business that Paul Hawken pointed out in *The Ecology of Commerce*. The first is to dramatically increase the productivity of natural resources. The second is to transition to biologically inspired production models. The concept of waste should be eliminated completely and materials should exist in closed loop cycles where every component either returns to the ecosystem or another production cycle. The third is to adopt a solutions-based business model. Instead of the old business model based on the sale of goods, the new model responds to customer needs in the most appropriate way such as a service of illumination rather than a light-bulb. The new model implies a new perception of value where instead of seeking affluence as measured by material goods, one seeks well-being as measured by satisfaction of changing "expectations of quality, utility and performance" (Hawken et al., 1999, p. 146). Lastly, there must be a reinvestment in natural capital. Essentially, business must "restore, sustain and expand" (Hawken et al., 1999, p. 148) the planet's ecosystem. These four shifts are summarized in Figure 5.

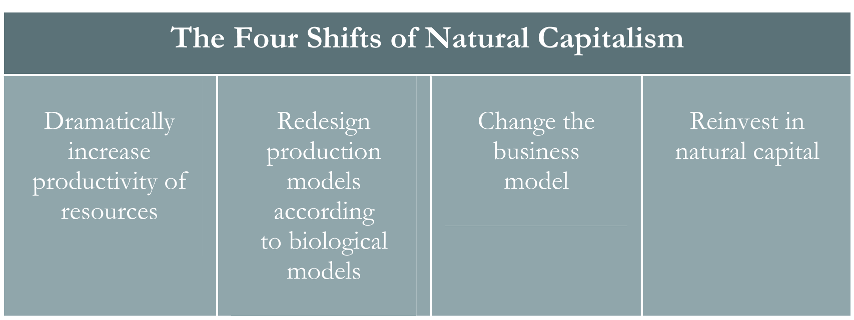


Figure 5: The Four Shifts of Natural Capitalism (Adapted from Hawken et al., 1999)

In the last two decades, under pressure from many sources, businesses have started to incorporate environmental management systems, tracking the environmental repercussions of their operations and attempting to somehow reduce these impacts. Industries across the globe now consider this approach, called eco-efficiency, to be the choice strategy of change (McDonough & Braungart, 2002). Businesses like this approach because ultimately, eco-efficiency uncovers inefficiencies that are expensive. Finding ways to use less primary resources, reduce energy consumption and revalorize by-products are all ways for companies to reduce costs. By doing more with less, companies are saving enormous sums of money and are incrementally reducing their environmental impact. As defined by the World Business Council for Sustainable Development (WBCSD),

> Eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the Earth's estimated carrying capacity. (Madden, Young, Brady, & Hall, 2007, p. 15)

In short, it is concerned with creating more with less. As outlined in the *Eco-Efficiency Module* published by the World Council on Sustainable Business, eco-efficiency highlights four main opportunities for environmental impact reduction: re-engineer processes so as to reduce consumption of resources, reduce pollution and avoid risks, while simultaneously reducing costs; work with other companies to find a second life for by-products; redesign products according to ecodesign strategies; and re-think markets to find new ways of meeting customer needs and reshaping product demand and supply completely[2]. The four main opportunities of eco-efficiency are represented below in Figure 6. Eco-efficiency is also associated with numerous tools for addressing these opportunities (see Appendix 5: The Four Tools of Eco-Efficiency).

Four Opportunities of Eco-Efficiency			
Re-engineer Processes	Revalorize By-products	Redesign Products	Re-Think Markets

Figure 6: Opportunities of Eco-Efficiency (Madden et al., 2007)

[2] Re-thinking markets is a similar approach to switching to a solutions-based business model advocated by Hawken et al in Natural Capitalism.

Eco-efficiency does have some limitations though. Firstly, eco-efficiency combines only two of sustainable development's three elements – economic benefit and environmental performance – while leaving the third, social progress, outside its embrace. Some companies who have adopted eco-efficiency strategies consider social value, but it is not a factor that is directly part of the eco-efficiency model. Secondly, it has the limitation of relative progress. If all companies become 5% more eco-efficient each year, while their output increases by 10% each year, then they may be improving eco-efficiency while moving away from sustainable development. Ultimately, eco-efficiency may not be the ideal model for sustainable business, despite being the most widely adopted one.

One of the most outspoken designers against eco-efficiency as the only necessary strategy of change is William McDonough. William McDonough is a product designer and architect, founder of the Institute of Sustainable Design and Commerce, author of the Hanover Principles on Sustainable Design, and recipient of the Presidential Award for Sustainable Development. In the book *Cradle to Cradle: Remaking the Way We Make Things* (2002), McDonough and chemist Michael Braungart outline their vision of how industry can move beyond eco-efficiency to eco-effectiveness and beyond sustainable development to regenerative growth. The book continues by explaining how the four R's - reduce, reuse, recycle and regulate – are simply ways of being less bad and are not suited for long term sustainability. The question must be asked: "What would it mean to be 100 percent good?" (McDonough & Braungart, 2002, p. 67). McDonough and Braungart propose eco-effectiveness as the strategy to shift industry to a model that is 100 percent good. Eco-effectiveness, as it is presented, promotes regeneration as opposed to depletion and designs that celebrate interdependence with other living systems. This model is based on two general principles: waste equals food, and respect diversity.

The first principle, waste equals food, is where the title *Cradle to Cradle* stems from. The authors propose that products are no longer designed to go along the linear path of cradle to grave but are designed with closed loop material flows that allow products live in an endless cradle to cradle cycle. To achieve this ideal, the authors propose that all materials are designed to fit into one of two material metabolisms as a technical nutrient or a biological nutrient. All technical nutrients are materials that are intended to go back into the technical cycle or technical metabolism and can be "upcycled", in that they are recycled without losing any of their original properties. All biological nutrients are completely benign and are consumed by microorganisms in the soil and biodegrade. The second principle, celebrate diversity, says that all sustainability is local. The authors argue that we need to model our systems on nature and develop a rich connection to place.

The current approach of sustainable design advocates a needs-based approach to problem solving to bring the most environmentally and socially appropriate solutions to market. In some cases this will mean redesigning the entire way that an organization creates value. Given that one of the underlying principles of all frameworks for sustainable business is that there needs to be a shift to new business models, both designers and business leaders need to understand what exactly a business model is and how it can be innovated.

2.6 Product Design and Business Models

Understanding business models is the first step to both business model innovation and designing completely new ones if necessary. Better business models, that create real value in more financially, ecologically and socially sustainable ways will stand to improve many people's lives (Kaplan, 2009). As discussed above, there has been an expansion of the design field beyond just the design of objects to the design of services and systems as well. However, the notion of using design processes and methodologies in the context of business model design and innovation lies at the heart of the intersection between business models and product design. As Osterwalder explains:

> A designer's business involves the relentless inquiry into the best possible way to create the new, discover the unexplored, or achieve the functional. A designer's job is to extend the boundaries of thought, to generate new options, and, ultimately, to create value for users. This requires the ability to imagine 'that which does not exist.' We are convinced that the tools and attitude of the design profession are prerequisites for success in the business model generation. (Osterwalder & Pigneur, 2009, p. 125)

In fact, many thought leaders in design and business see huge potential for the use of design processes, methodologies and sensibilities in all aspects of business decision-making by the collective workforce of any organization (T. Brown, 2009; Carr, Halliday, King, Liedtka, & Lockwood, 2010; Conley, 2004; Lockwood, 2010; Martin, 2009; Osterwalder & Pigneur, 2009; Zaccai, 2010). Historically, design was considered very separate from business, since it was primarily outsourced as a service in most situations (Conley, 2004). The distinction is starting to be less pronounced, however, as design is more and more thought of as a methodology for creative problem solving in any context. In the recently published book, *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation* (2009), Tim Brown presents the case for all employees of a business to adopt the way of thinking that his design firm, IDEO, has used to become thought of as one of the world's most innovative companies. Rodger Martin, Dean of the Rotman School of Management, has recently published a book called *The Design of Business: Why Design Thinking is the Next Competitive Advantage* (2009) in which he explains how companies can get stuck perfecting what they do, when to remain competitive, all employees could be thinking like a designer, using abductive reasoning to imagine what might be next. Spurred by burgeoning attention to the topic in the popular business press, a study by the Design Management Institute is looking at how the methods, techniques, and processes, traditionally associated with design and designers, have been adopted within established business organizations. The preliminary hypothesis is that using these design sensibilities is in fact growing in influence in business organizations and its trajectory would follow that of other broadly recognized management thinking such as Total Quality Management (TQM) (Carr et al., 2010). Even if that level of implementation is not reached quickly, it is hard to imagine that the merits of thinking like a designer, which can be thought of as properly balancing left and right brain reasoning, will not eventually become recognized as an asset sought after in all employees.

Some of the thought leaders who advocate using design processes and methodologies in business have identified the specific aspects of thinking like a designer that are so valuable to business contexts. Giannfranco Zaccai of the global design firm Continuum describes the designerly way of thinking as *personal* (user-centered), *collaborative* (team focused), *interpretive* (what is the problem behind the problem), *objective* (thinking about what could be possible) and *experimental* (fail early to succeed) (Zaccai, 2010). Chris Conley points out similar aspects of designing that add value to the spectrum of activities within the business enterprise: the ability to understand the context and to reframe problems, to work abstractly, to visualize, to use form to embody and communicate ideas, to discover critical relationships, and to generate meaningful alternatives (Conley, 2004). In 2005, when called upon by Procter & Gamble to inject some design sensibility into their organization, David Kelley, Dean of the Hasso Platter Institute of Design at Stanford, Patrick Whitney, Dean of the Institute of Design at the Illinois Institute of Technology, and Rodger Martin, Dean of the Rotman School of Management broke down design sensibilities into three essential components: "deep and holistic user understanding; visualization of new possibilities, prototyping and refining; and the creation of a new activity system to bring the nascent idea to reality and profitable operation" (Martin, 2009, p. 88). Their description of design thinking for business can be thought of as a way to introduce design thinking into all aspects of business decision making.

However, some consider the greatest payout of using design sensibilities in business lies in the design of strategies and business models for organizational performance that creates both economic and human value. As Heather Fraser of the Rotman School of Management explains, "there is compelling evidence that the methods and mindsets behind great design in fields such as engineering, industrial design and architecture are equally powerful in designing an enterprise model" (Fraser, 2010, in Lockwood, 2010 p. 37). Fraser distils business model design down to three fundamental stages: empathy and deep user understanding, concept visualization, and strategic business design. Empathy and deep user understanding is about using a broad lens to understand your customer and other stakeholders through how they feel, and how their needs surrounding their activities link to other parts of their lives. Concept visualization is about exploring all possibilities and ideally, finding ways to test concepts with users to allow for evaluation and refinement. Lastly, strategic business design is about aligning concepts with future reality, identifying the key activities to operationalize the business model, and identifying drivers for success. These three stages, represented below in Figure 7, are almost directly parallel to the three stages of the design process of inspiration, ideation and implementation that Tim Brown follows.

Figure 7: The Gears of Business Design (Fraser, 2010, in Lockwood, 2010 p. 36)

Osterwalder also advocates using the designer's toolbox for successful business model design and innovation (Osterwalder & Pigneur, 2009). He identifies the five main tools that should be used for business model design as:

- **Customer insights:** Study the customer extensively to truly meet their needs and switch from an organization-centric view to a customer-centric view.
- **Ideation:** Brainstorm and think outside of the box by ignoring status quo, stopping to focus on competitors, and challenging the norms.
- **Visual Thinking:** Make ideas visible to everyone and use graphic ways that communicate ideas clearly.
- **Prototyping:** Eliminate negative thinking by relying on the iterative process of prototyping, testing, evaluating, and refining.
- **Storytelling:** Flush out details of hypothetical scenarios and engage employees and inspire investors through storytelling.

2.7 Conclusion

As shown above, internal and external factors in the fields of design, business models, and sustainability, are increasingly making the intersection of these three fields a key area of interest in creating meaningful, sustainable solutions in the highly networked global economy. It should be noted that sustainable solutions in this context refers to:

> Products, services, hybrids or system changes that minimise negative and maximize positive sustainability impacts – economic, environmental, social and ethical – throughout and beyond life-cycle of existing products or solutions, while fulfilling acceptable societal demands/needs. (Charter & Tischner, 2001, p. 130).

In its most broad sense, design can be considered an activity that is concerned with changing an existing condition into a new one and industrial designers are using a user-centric approach to design, not just for products, but services and systems as well. Moreover, recognising design's role in sustainability, designers are pushing the boundaries of sustainable design to include the possibility of creating new sustainable systems and new forms of business. Business leaders as well are calling for industry to rethink the role of business and evolve beyond traditional destructive business models. Lastly, trends in environmental awareness, technology and globalization are catalyzing the understanding of business model theory and the tools for business model innovation. All of these factors converge on a problematic situation where designers, design managers, entrepreneurs, and all business decision-makers need to understand the relationship that exists between product design and business models, and the role that innovating on a product level and a business model level simultaneously can play in creating sustainable solutions.

Chapter 3. Research Problem

The goal of this research is to better understand the relationship between product design and business models in the context of sustainability. This "problem space" is represented by the grey area in Figure 8. This chapter will discuss how new production-consumption systems combined with new products or services are considered to yield the most potential for sustainable solutions. Furthermore, this research will explore if product innovation combined with business model innovation has the most potential for creating customer value. However, there is little literature and understanding about the relationship between business models and product design or about the benefits and limitations of combining business model innovation with product innovation. Without a proper understanding of the relationship that exists between product design and business models, or of the benefits and limitations of projects that consider both simultaneously, designers, design managers, and business decision makers will be unable to properly navigate the increasingly relevant context of the intersection between sustainability, product design and business models.

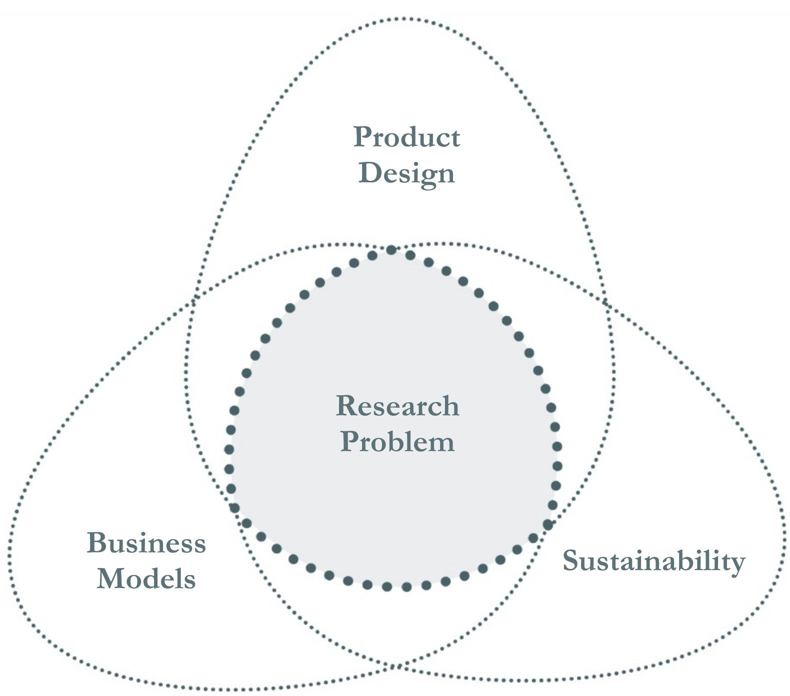


Figure 8: Research Model with the Problem Space Highlighted by the Grey Area

3.1 The Call for New Products, Services, Systems and Scenarios

The intersection between product design, business models, and sustainability, is already touched on by numerous authors and threads of research, although not explicitly using the term business model. When discussing sustainability on an industry level, the term "systems innovation" is sometimes used. In their book, *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy* (2004), Frank Elzen, Boelie Geels, and Ken Green argue that improvements in resource efficiencies of a factor of 2 may be possible through incremental innovation while a large jump up in efficiency (possibly by a factor of 10) may only be possible through systems innovation. They define systems innovation as large shifts from, for example, one transportation system to another or from one energy system to another. They also make note that there has been a widening in recent years of the analytical focus in sustainability, from clean products to sustainable systems. Such system innovations involve new technological artefacts, new markets, user practices, regulations, infrastructure and cultural meanings. On a micro or organizational level, these changes inevitably represent new business models.

The term 'production-consumption system' is also often used when discussing radical improvements in sustainability. Production and consumption models refers to the idea that the current industrial system is composed of both a supply side and a demand side, where the supply side is the domain of industry, and the demand side is the domain of society. Environmentally, the concept of efficiency in production is considered the responsibility of industry, while the concept of sufficiency in consumption is considered the responsibility of society (Vezzoli & Manzini, 2008). Essentially, to reduce the most environmental impacts, industry should do more with less, while at the same time society needs to curb its tendency to consume well above its needs. Ways of meeting needs of society that can offer efficiencies, while simultaneously reducing demand of produced goods, are considered innovations in the production and consumption model. On an organizational or micro level, new systems of production and consumption take the form of new business models.

A way to map the concepts of consumption-production systems and systems innovation can be seen in Figure 9. The model is based on innovation models more traditionally used in economics to depict the economic benefits of incremental, radical, behavioural and systems innovations (Dusch, Crilly, & Moultrie, 2010). In their book, *Design for Environmental Sustainability*, Vezzoli and Manzini describe four different "levels of intervention" that have an increasing potential to move from the status quo of the industrialized world to more sustainable systems (Vezzoli & Manzini, 2008). Each quadrant in the model corresponds to a level of intervention. Level one is environmental redesign of existing products (incremental innovation); level 2 is designing new products and services (radical innovation); level 3 is designing new production-consumption systems (behavioural innovation); and level four is creating new scenarios for sustainable life-styles (systems innovation). The horizontal axis represents the magnitude in changes in products and services (the production side). The vertical axis represents the magnitude of changes in consumption behaviour (the supply side). Evidently, the more innovation on each axis, the more one evolves from the status quo and the more potential there is for sustainability. As such, the upper right quadrant of systems innovation defined by major changes in both the demand side and the supply side is thought to hold the most potential for sustainability. This model is very much intended to represent the macro or industry level of the economy, not the organizational level. On the macro level, the term 'new scenarios' includes products, services, technologies and the supporting organisational, economic, regulatory, knowledge, and cultural structures.

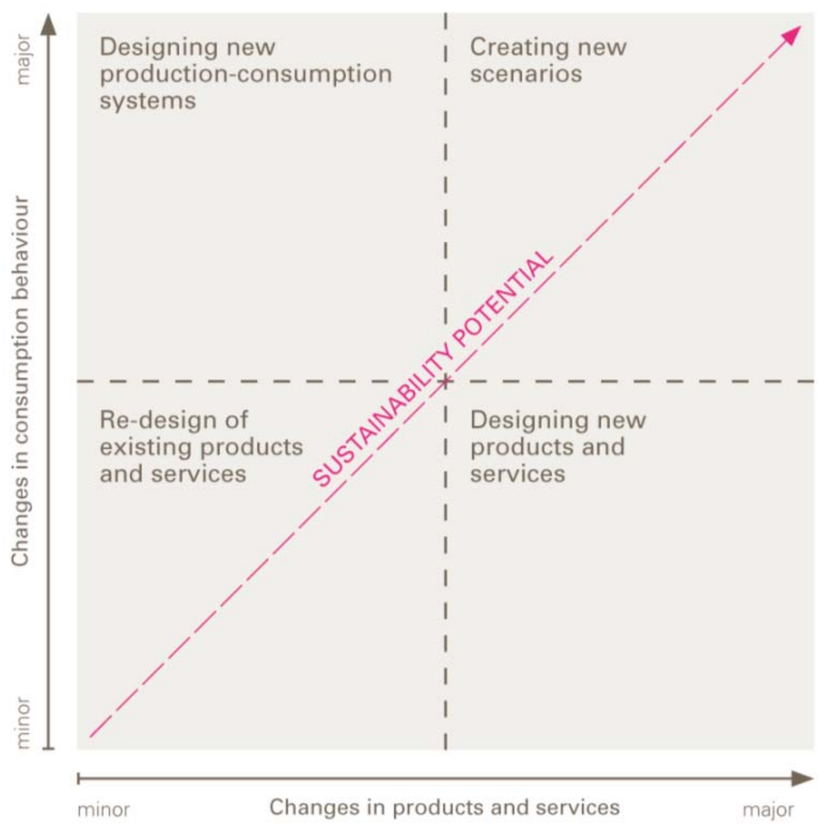


Figure 9: The four levels of sustainable intervention (Dusch et al., 2010)

3.2 What is the Relationship between Product Design and Business Models in the Context of Sustainability?

The intention of this research is to bring the notion of systems innovation for sustainability down to an organizational level. Looking back to the ecodesign strategies outlined by Brezet and Hemel, certain questions need to be addressed before any actual product design decisions are made. In the first strategy proposed, the focus is not on a physical product but on the function of a product system and the way it fulfills a need. This type of thinking has the potential to alter the business model of the firm, for the purpose of reducing environmental impacts. For example, "Should management decide to focus less on the sale of products and more on providing a service, then the company is committed to developing a new business rather than just a product" (Brezet and Hemel, 1997, p. 145). This places a new responsibility on the designer and demands a new way of thinking.

> Introducing systems innovation within design for sustainability requires new skills. First, it means that we have to learn to design integrated products and services. This brings up the issue that is relatively new in current design practice and requires designers to learn how to design the stakeholder configuration, in order to find solutions that might combine the economic and environmental interests. (Vezzoli & Manzini, 2008, p. 212)

Given the definition of the business model canvas, it can be used as a way to help designers and managers develop the required 'integrated products and services' and to better 'understand the stakeholder configuration to combine economic and environmental interests'. Saul Kaplan believes strongly in the potential for business model innovation to play a role in systems innovation. In a presentation given at the Ontario College of Art and Design, Kaplan explained to the audience of student designers, faculty and visiting professionals how he believes business model innovation can lead to systems innovation in areas such as healthcare, education and environmental management (Kaplan, 2009). He uses a model with a similar architecture as the previous model to represent the potential for combining business model innovation with product innovation (Figure 10). Other models which represent the macro level of systems innovation are not easily used to operationalize the types of system innovation that dramatically increase environmental efficiency.

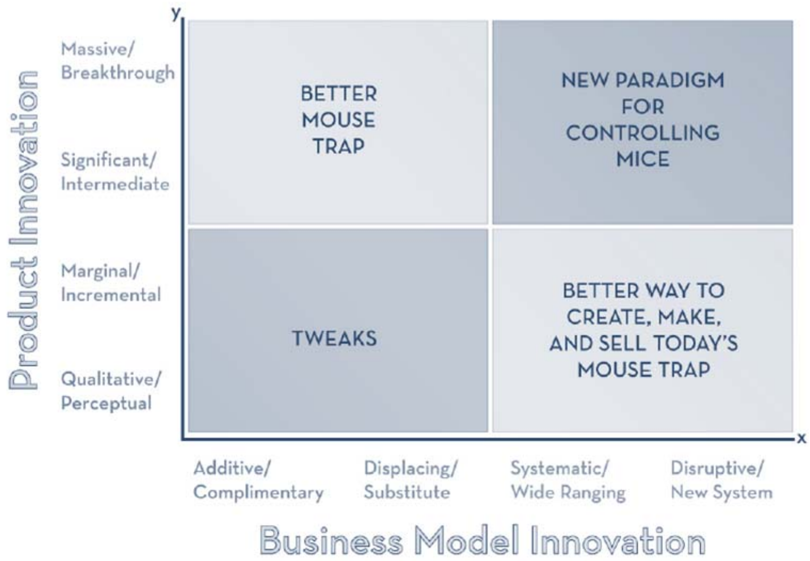


Figure 10: Business Model Innovation and Product Innovation (Kaplan, 2009)

Kaplan's model however, very much rooted on an organizational level, uses two axis that are increasingly becoming defined and understood as having similar processes and methodologies, namely business model innovation and product innovation. Furthermore, both are very much rooted in a human-centered approach. As is the case in the model above, the more innovation along each axis, the more one evolves from the status quo and the greater the propensity for changing to sustainable solutions.

Kaplan holds the position that business model innovation and product innovation need to go hand in hand to get to systemic or disruptive innovative. Bill Buxton makes the case that combining business model innovation and product innovation offers the most potential for creating economic value. Comparing Apple and Dell in the mid 2000's, he describes Apple as having beautiful, design intense products but with a traditional process (business model). Dell has boring products with no technical innovation, but they have a very innovative process of selling and manufacturing their products (an innovative business model). Buxton is clear to make the distinction between product and process and goes on to say that "innovation in process and design trumps innovation in process alone" (Buxton, 2008). The fact that once Apple innovated their business model as well, with the advent of the iTunes/iPod and App Store/iPhone ecosystems, they quickly surpassed Dell and many other competitors in market share, attests to the benefits of innovating on a product and business model level simultaneously. In today's business landscape, innovation needs to happen on both a business model level as well as on a technological or product level (Chesborough, 2007). The relationship between these two activities that evidently need to be carried out simultaneously, however, is not well understood. Also, how these two activities can be cantilevered into the realm of creating sustainable solutions is not well documented. The key focus of this research is to create a better understanding of how product design and business model innovation are related and can be practiced simultaneously to create more sustainable solutions.

Primary research question:

In what ways are product design and business models related in organizations where sustainability is a top priority?

Secondary research questions:

A) Can product design contribute to the success of a business model?

B) Can elements of a business model contribute to the success of a product design?

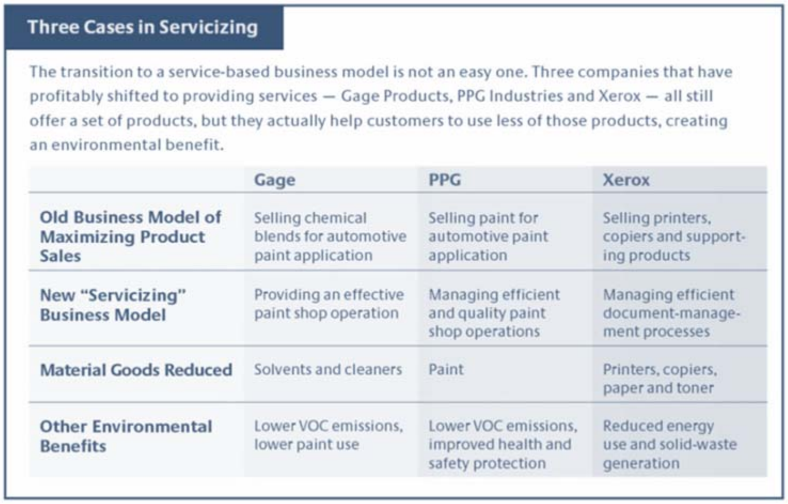
C) What are the benefits and limitations of considering business model and product innovation simultaneously?

3.3 The Limits of Product Service Systems

The closest that current literature gets to identifying the relationship between sustainability, product design and business models is under the notion of Product Service Systems (PSS). As far back as Paul Hawken in the 1990's, there has been a push to evolve from meeting customer's needs through selling products to offering less resource intensive services. The winter 2000 issue of *The Journal of Industrial Ecology*, entitled "From Products to Services", tackles the issues raised by a shift from products to services. In the issue, Reid Lifset summarizes the concept as follows:

> The core concept is that, as consumers, we seek not the product, but rather the functionality that it offers us; and further, if economic relationships can be structured to encourage this shift in focus, many opportunities for meeting human needs with fewer physical goods will emerge. This dematerialization will, in turn, lead to fewer environmental impacts. (Lifset, 2000, p. 1)

In the *Design Issues* article, "Sustainability Through Servicizing" (2007), Sandra Rothenberg makes the case that "servicizing" your products can make one's business more competitive and more sustainable (see Figure 11).



Three Cases in Servicizing

The transition to a service-based business model is not an easy one. Three companies that have profitably shifted to providing services — Gage Products, PPG Industries and Xerox — all still offer a set of products, but they actually help customers to use less of those products, creating an environmental benefit.

	Gage	PPG	Xerox
Old Business Model of Maximizing Product Sales	Selling chemical blends for automotive paint application	Selling paint for automotive paint application	Selling printers, copiers and supporting products
New "Servicizing" Business Model	Providing an effective paint shop operation	Managing efficient and quality paint shop operations	Managing efficient document-management processes
Material Goods Reduced	Solvents and cleaners	Paint	Printers, copiers, paper and toner
Other Environmental Benefits	Lower VOC emissions, lower paint use	Lower VOC emissions, improved health and safety protection	Reduced energy use and solid-waste generation

Figure 11: Three Cases in Servicizing (Rothenberg, 2007)

She uses three case studies to illustrate the different ways servicization, or the implementation of a PSS into the business model, can be beneficial both economically and environmentally. Figure 11 presents examples of how addressing the environmental impacts of the products that a company produces can lead to far greater changes than just designing products that have fewer negative impacts. In each case, the organization realized that their business model of simply trying to sell the most products clearly had conflicting incentives with implementing a sustainable design strategy. The important point to remember is that economic relationships play a role in encouraging this shift. It is up to the organizations themselves to change their business models so as to focus not on the product, but on the needs of its customers.

When an organization's offering is an integrated ecosystem of products and services, the resulting business model is called a product service system. A PSS is a business model that combines products and services in various degrees to meet specific user needs (Tukker, 2004). The model allows firms to create new sources of added value and competitiveness, by fulfilling client needs in integrated and customized ways. They can also build unique relationships with clients and enhance customer loyalty because of their unique, more integrated experience. The various forms of PSS are represented in Figure 12.

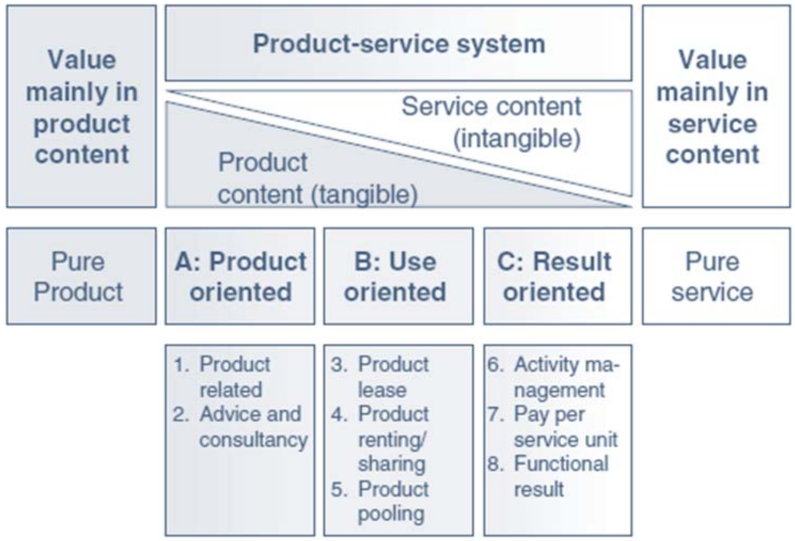


Figure 12: Main and sub categories of PSS (Tukker, 2004)

As depicted in the model, a PSS can exist on the continuum between purely a product or purely a service. The three specified categories are product oriented, use oriented, and result oriented, each with their respective sub categories. PSS as a concept falls directly in the intersection between product design, business models, and sustainability. However, this type of business model innovation, which is based entirely on the notion of adding at least some service component to the customer value proposition falls mainly into the revenue structure building block of the business model, which is known to be just one of nine building blocks of a business model. This research intends to better understand the ways that product innovation and business model innovation can be related to all building blocks of the business model, not just the revenue structure or the customer value proposition.

3.4 Purpose of the Study

The objective of this research is to help decision makers better understand the relationship between product design and business models in the context of sustainability. Business model theory has matured to the point where thought leaders in the field have come to a general consensus of the definition of a business model and what elements come together to make up a business model. Understanding business model theory will help designers adopt a holistic approach to problem solving, which is necessary in both sustainable design projects and traditional design projects alike. Sustainable design strategies call for a needs-based approach that seeks to meet needs in the most appropriate way, even if the solution requires a new business model. This research intends to uncover whether better understanding the relationship between product design and business models can help open up possible solutions that may otherwise have been impossible. Perhaps design problems can be partially solved through business model innovation or vice versa. Furthermore, designers are called on to propose solutions to users' needs, and these needs are becoming increasingly complex in the face of rapidly changing social, environmental, economic and technological conditions. Understanding how business model innovation and product design can be practiced simultaneously to create sustainable and integrated experiences that meet users' complex needs will benefit all stakeholders.

The design field is moving toward using a much broader application of design competence. A better understanding of the relationship between design and business models will help align the thinking of designers and business decision makers. Many thinkers in design and business are saying that designers need to feel comfortable leaving behind the title of designer for such titles as manager, strategist or vice president (Conley, 2004) and that business practitioners need to start thinking like designers (T. Brown, 2009; Carr et al., 2010; Conley, 2004; Lockwood, 2010; Martin, 2009; Osterwalder & Pigneur, 2009; Zaccai, 2010). This research intends to help problem solvers on both sides integrate the thinking of the other. Ultimately, it concerns designers, managers, executives and all business leaders looking to adopt a holistic approach to problem solving.

A secondary objective of this research is to help designers better understand the business model in which their products will exist. Helping designers see their projects through a well-defined business model lens may open up new opportunities for innovation. Keeping the needs of the user as the top priority, the product design can be optimized for the business model, increasing the likelihood for the product to be successful and the business to stay competitive in the ever increasingly competitive market.

3.5 Importance of the Study

This research aims to help stakeholders develop sustainable value for the market. Leveraging a holistic understanding of the solution landscape, designers and business leaders can perhaps be helped to move beyond incremental improvement and provide transformational change to sustainable design problems. Incremental improvements in efficiency, when aggregated across the whole economy, reduce environmental impacts. But as the economy and the use of resources expand at a faster rate than increases in efficiency do, the net environmental impacts of the industrial system continue to grow. Unlimited growth in a system of limited resources, when growth is synonymous with increased resource use, cannot be sustainable. A better understanding of how to think on a product and business model level simultaneously stands to help decision-makers and stakeholders create sustainable solutions that create more value, reduce demand for consumption, and dramatically increase resource efficiency.

In the age of globalization, many organizations are expanding into developing markets such as India and China, drawn by the billions of potential customers. However, given current resource efficiencies, these markets cannot adopt the lifestyles of industrialized countries without devastating effects to the natural and social environments. Through this disregard for sustainability considerations, which governments are either encouraging or having difficulty controlling, the carrying capacity of the planet is being compromised. The population urgently needs sustainable solutions that fulfil needs, enable people to live an acceptable quality of life, and create equal opportunities for socio-cultural and economic development, especially in less-industrialised countries (Tischner & Verkuijl, 2006).

Meanwhile, as more and more needs are met in industrialized countries, people increasingly desire sophisticated and meaningful experiences. The experiences will not be simple products but they will be complex combinations of products, services, spaces, and information (T. Brown, 2008). As the products, services and experiences become increasingly complex, so too will the business models of the organizations that provide them. This research intends to help all stakeholders navigate this new business context that Osterwalder & Pigneur refer to as the business model generation (Osterwalder & Pigneur, 2009).

On an academic level, this research aims to build on the existing theory in the three fields of product design, business models, and sustainability as well as in the overlapping areas of these three fields, namely, sustainable business, sustainable design, and business model design. Lastly, this work will strengthen the theory in areas such as systems innovation and product service systems that fall in the intersection of the three fields that make up the context of the problem that this research addresses.

Chapter 4. Methodology

4.1 A Complex Systems Approach Grounded in a Pragmatist Paradigm

4.1.1 The Pragmatist Paradigm

Design research has historically been based on a positivist or post-positivist approach. The positivist/postpositivist paradigm takes a scientific approach to research and works from within a realist ontology and an objective epistemology and is considered reductionistic and logical. Herbert Simon's *The Sciences of the Artificial* (1969), in which Simon pleaded for the development of "a science of design" in the universities, is thought of as the culmination of an era that looked at design as a problem solving method based on science, technology and rationalism (Cross, 2007). But over the last few decades, design research has moved away from positivist, mechanist methods of research toward a more constructivist approach. The constructivist approach assumes a relativist ontology where there are multiple realities, a subjectivist epistemology where knower and responder co-create understandings and it uses a naturalistic set of methodologies, meaning they are set in the natural world (Denzin & Lincoln, 2005). Donald Schön can be considered one of the catalysts of this evolution in that he "explicitly challenged the positivist doctrine underlying much of the 'design science' movement, and offered instead a constructivist paradigm" (Cross, 2007, p. 45). Schön criticised Simon's science of design for using approaches that can only be applied to well-formed problems, while in practice, design problems are messy and ill-defined. He proposed an epistemology that was more in line with the artistic and intuitive processes that designers use to deal with ambiguity and uncertainty.

Despite being grounded in theory and current trends in research in the fields of design, sustainability and business models, this study directly addresses practice and practical concerns. The primary concern of this study is the better understanding the complex relationship between product design and business models to help create more valuable and sustainable solutions for society. This research is not committed to any one system of philosophy and reality but more concerned with using the best approach to answer the research question in a way that can be applied in practice. As such, it is very much based in a pragmatist paradigm, where "instead of a focus on methods, the important aspect of research is the problem being studied and the questions asked about this problem" (Creswell, 2007, p. 22-23). In a pragmatist paradigm, the focus is placed heavily on the actions, situation and consequences of the research inquiry, as opposed to the focus being on antecedent conditions, such as in post-positivism. The priority is in finding solutions to problems and being free to choose the best approach needed.

4.1.2 Why is the pragmatist paradigm appropriate for design research?

The pragmatist paradigm is grounded in the philosophy of pragmatism which shares many fundamental beliefs with modern design thinking. Pragmatism emerged as a philosophy at the end of the 19th century, and the individual thinkers who contributed most to the formation and articulation of pragmatism, Charles Sanders Pierce, William James, and John Dewey, are considered by some to be the three greatest American philosophers (Thayer, 1981). Much like designers of today, these early pragmatists proposed to reorient the assessment of theories around the capacity for the theory to solve human problems. They believed that the "mandate of science is not to find truth or reality, the existence of which are perpetually in dispute, but to facilitate human problem-solving" (Powell, 2001, p. 884). Early pragmatists were frustrated by the interminable and fruitless debates associated with the philosophy of their time. As part of their overall commitment to problem solving, they emphasized their conception of experience and insisted that ideas should be tested in practice to assess their validity (Kloppenberg, 1996). The pragmatist's emphasis on real world testing parallels the iterative nature of the design process that uses prototyping and refinement to arrive at a desirable, viable and feasible solution. Pragmatism makes the links between theory and praxis part of the problem solving process with an emphasis on taking action. In another similarity to the discipline of design, "the core reflection process is connected to action outcomes that involve manipulating material and social factors in a given context" (Denzin & Lincoln, 2005, p. 53). In fact, pragmatism is actually derived from the Greek word *pragma* which means action, from which the words 'practice' and 'practical' come (James, 1907). Ultimately, pragmatism is about making people's lives better. The problem solving, testing and taking action associated with pragmatism is all a function of the end goal which is increasing human well-being. Richard Rorty, an American philosopher often associated with the pragmatist school of thought, defines pragmatism as "the claim that the function of inquiry is, in Bacon's words, to 'relieve and benefit the condition of man' – to make us happier by enabling us to cope more successfully with the physical environment and with each other"

(Rorty, 1991, p. 27). This goal is congruent with both the goal of design as a discipline and with the purpose of this research study.

Pragmatism is grounded in problem-solving, linking theory and practice, testing ideas, creating actionable outcomes, and increasing well-being – almost identical concepts as those forming the foundation of the discipline of design. Given this common foundation, the pragmatist paradigm is an appropriate fit for this design research.

4.1.3 A Complex Systems Approach

While many thought leaders in the design community were contemplating the role of science in design and advocating an evolution beyond the scientific-based positivist approach to design methods, some in the science community were exploring new ways of perceiving the world, which stood to have immeasurable impacts on global society. These scientists were building on the emerging popularity of systems thinking and gaining an understanding of the sciences of complexity (J. Broadbent, 2004). Given the nature of the research question of this study, applying an understanding of complexity and using a complex systems approach will be invaluable to addressing the holistic nature of the problem at hand.

Systems theory emerged in the middle of the 20th century, after biologists such as von Bertalanffy realised that reductionism was unsuited to understanding biological phenomena. By the end of the 1970's systems thinking had become applicable to a multitude of fields, and due to its ability to be applied to virtually any other discipline, systems thinking is considered a meta-discipline (Checkland, 1981). In its most basic sense, a system can be thought of as an assembly or a set of related elements where the elements of a system can be concepts, objects, subjects or any combination of the three (Gigich, 1991). Peter Checkland, one of the leaders in systems thinking, points out that just as important as the elements that make up a system, however, are the relationships that exist among the elements. He identifies two key properties of a system:

1) *Emergence* and *Hierarchy*: a whole system may have properties that do not apply to the individual parts that make up the whole. These properties are called *emergent* properties and imply that reality consists of layers of *hierarchy* (not in the authoritarian sense).

2) *Communication* and *Control*: a system can survive shocks from the environment through processes in which there is *communication* of information for purposes of regulation or *control*. (Checkland & Scholes, 1999)

By these criteria, one can understand how an organism is a system composed of cells. The organism has properties that the individual cells do not (emergence) and the whole organism is thus greater than the sum of its parts (hierarchy). Further, as an organism get shocks from its environment, its cells can communicate with each other to adapt and regulate (control) the organism. Given this understanding of systems, one can see how systems are pervasive in nature, in the created environment and technology, and in social structures. Products made of multiple components, buildings, cities, organizations, institutions, and governments, are all systems. To use systems thinking is to keep in mind the adaptive whole that may be able to survive in a changing environment.

Edgar Morin, a thought leader in the field of systems thinking and complexity, credits the emergence of complexity to the first connections that were made between systems theory, cybernetics, and information theory. Checkland notes that that complexity is present whenever there is more criteria than one scientist can handle (Checkland, 1981), but by all accounts, complexity results from the many intricate interactions that society has with its own created systems (Gigich, 1991). A complex system can be thought of as a system that is made up of a large number of parts that interact in a nonsimple way (Simon, 1962), or as Edgar Morin puts it, consists of a "multiplicity of interrelated processes, interdependent and retroactively associated" (Morin, 2007). The same way that biological organisms have used "complexification" to improve their ability to adapt to their environment, so too have socio-cultural systems, being composed of more elements, more kinds of elements, with more integration. In the same ways, products, processes and organizations have become increasingly complex.

4.1.4 Why is a Complex Systems Approach Appropriate for Design Research

The holistic sciences (general systems theory, systems thinking, complexity theory, etc.) of the mid-twentieth century offer a whole new way of looking at the world, and the design field stands to gain a lot from seeing the world through this lens. Systems and complexity theories have already played a key role in the evolution of the design process beyond the mechanistic model (J. A. Broadbent & Cross, 2003; Findeli, 2001). As the design field expands to include all of Buchanan's four orders of design - communication, construction, strategic planning and systemic integration – a complex systems approach will be increasingly pragmatic and perhaps essential. Problem complexity in organizational settings is starting to evolve beyond the utility of many of the available methods, and as systemic activities become pervasive in our society, methodologies that afford an understanding of the interlinked nature of systems are needed. Alain Findeli is a design scholar who sees great potential for complex systems approach in design. In his article, "Rethinking Design Education for the 21st Century: Theoretical, Methodological, and Ethical Discussion" (2001), he makes note that Lazlo Moholy-Nagy saw the ability to see everything in relationship as the key to our age. The following paragraph summarizes Findeli's view that the context for today's designers is crying out for a complex systems approach in the design process:

> The outer world is much more than what even environmentalists and ecodesigners call the environment, usually reduced to its biophysical aspects. Here, we also are dealing with various interrelating subsystems, which function and evolve according to very different logics: the technical or man-made world, the biophysical world, the social world, and the symbolic world or "semiocosm." (…) My suggestion is that we should not restrict ourselves thus, but, instead, open up the scope of inquiry, i.e., in systems theory terms, and push back the boundaries of our system in order to include other important aspects of the world in which design is practiced. (Findeli, 2001, p. 11)

He notes that many interacting subsystems lead to a level of complexity that the designer must find a way to manage. The further one can push back the boundary of our system being considered, the better the chance of creating solutions that stick, despite the multiplicity of interrelating elements acting in the context in which those solutions exist.

Design research can be considered as part of a cycle in which design research informs design practice and design practice informs design research. The growing complexity and systemic nature of the contexts and issues relevant to both design research and practice, suggest that seeing the world as made up of systems and subsystems, with both elements to identify and relationships to understand, is a highly relevant and practical approach.

4.2 Qualitative Research through a Case Study - Research in Action Hybrid

4.2.1 Qualitative Research

The first step in choosing the appropriate methodology for this research began with a close look at the research question. What is the *telos* or purpose of this research? To review what has been stated above, the primary research question of this study is: In what ways are product design and business models related in organizations where sustainability is a top priority? Three sub-questions of this study are: 1) Can product design contribute to the success of a business model? 2) Can elements of a business model contribute to the success of a product design? and 3) What are the benefits and limitations of considering business model and product innovation simultaneously? Looking at the research holistically, the underlying intent is to uncover and better understand relationships. Among the many reasons to use qualitative research presented by John Creswell in *Qualitative Inquiry and Research Design: Choosing Among Five Approaches* (2007), the two that stand out are because one is seeking a complex, detailed understanding of an issue and because quantitative research just doesn't fit the problem - both of which apply in the case of this research. Ultimately, this research intends to identify and qualify the nature of some of the relationships that exist between product design and business models. Qualitative research methodology is best suited for this end. Furthermore, given the complex systems approach to this research, the organizations that are described by business models and that carry out product design are viewed as complex systems, and "a system, especially a human or social system, is best understood from within, through a qualitative, phenomenological approach" (Findeli, 2001, p. 12).

As qualitative research, this study can be expected to have certain characteristics. Firstly, the researcher is a key instrument since he will gather the data and analyse the results; there will be multiple sources of data as opposed to a single source; the research will be an emergent design in that the research plan may shift and be somewhat organic once the research begins; the topic will be viewed through a theoretical lens, in this case through a theoretical framework using a complex systems approach and Osterwalder's Business Model Canvas; the inquiry will be interpretative in that the analysis will be based on the interpretation of the researcher; and finally, the research will create a holistic account of the problem studied (Creswell, 2007).

4.2.2 A Hybrid Methodology of Case Study and Research in Action

The specific methodology used for this research is a combination of case study and research in action. Stemming from the pragmatic paradigm of this research, the research is designed to best answer the question without being married to any one type of methodology. In some cases, the pragmatic paradigm leads to a combination of qualitative and quantitative methodologies. In this case, the research is entirely qualitative but does make use of both a case study approach and a research in action approach. In order to get the most complete data to answer the research question (given time and financial constraints), three organizations that have sustainability as a top priority have been identified and explored through case-study analyses. It should be noted that case study is not necessarily a methodological choice but a choice of what is to be studied (Stake, 2005). Any given case can be studied holistically, analytically, by repeated measures or hermeneutically, organically or culturally, or by mixed methods. For more detailed information on the methods of analysis applied in this research study, see the analysis section below.

The three cases have been identified and chosen as case studies based on their relevance to the research question. They are cases where business model innovation was used as a tool to compliment sustainable product design with the goal of creating transformational change in their industries. The goal of these case studies is to dissect companies that are addressing sustainability from both a product and a business model perspective, and to analyse the relationship between product design and business model innovation in the context of that company's sustainability goals.

The first chosen case is Interface Inc, a transnational industry leading modular carpet tile manufacturer based in Atlanta, Georgia. The second case study is Better Place, a global provider of infrastructure for charging electric vehicles. The third case is a project that was carried out as action-research, where a company concept was developed and analysed according to the same criteria as the first two case studies. The company concept is called Metacycle, and is essentially a website that crowd sources ways to reuse end-of-life products, and uses an international partner network of direct digital manufacturers to locally manufacture products sold to its customer base through the company website. The practice of creating Metacycle was itself a research in action that was iterative and informative in further answering the research question and sub questions. Put simply, action research is learning by doing – a person or a group of people identify a problem, do something to resolve it, see how successful their efforts were, and if not satisfied, try again. It can be seen as a way of investigating professional experience by linking the practice and the analysis of practice in a continuous cycle (Winter, 1996). The aim of action research is two tiered in that it aims to both respond to the need of the person or group involved, as well as advance the goals and knowledge of the field in which the research is done. Thus, there is "a dual commitment in action research to study a system and concurrently collaborate with members of the system in changing it in what is together regarded as a desirable direction" (Gilmore, Krantz, & Ramirez, 1986). An emphasis on the scientific study where intervention is informed by theoretical considerations is what differentiates this type of research from general consulting, professional practices or daily problem solving.

Action research is a congruent fit with the complex systems approach applied to this research in that action research carried out with a systemic perspective stands to broaden action, deepen research, and construct meaning that resonates with our experiences in a highly systemic world (Flood, 2001).

4.3 Analysis

To answer the research question (represented by Figure 13), each of the three cases is analysed using a complex systems approach.

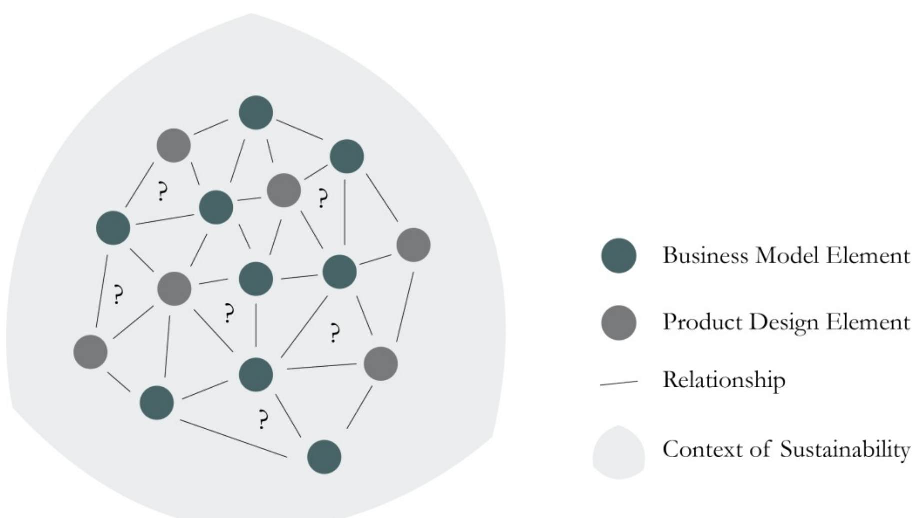


Figure 13: Model of Problem Space Depicting Unknown Relationships

The cases are broken down into their individual elements and the relationships between certain elements in the system are identified and analysed. The complex systems approach is fundamental to the way that this analysis is carried out, in that "the concept of system has always played a fundamental role in defining every set of relations among component parts that form a whole" (Morin, 1992, p. 372). The analytical process used to make sense of these relationships is depicted in Figure 14.

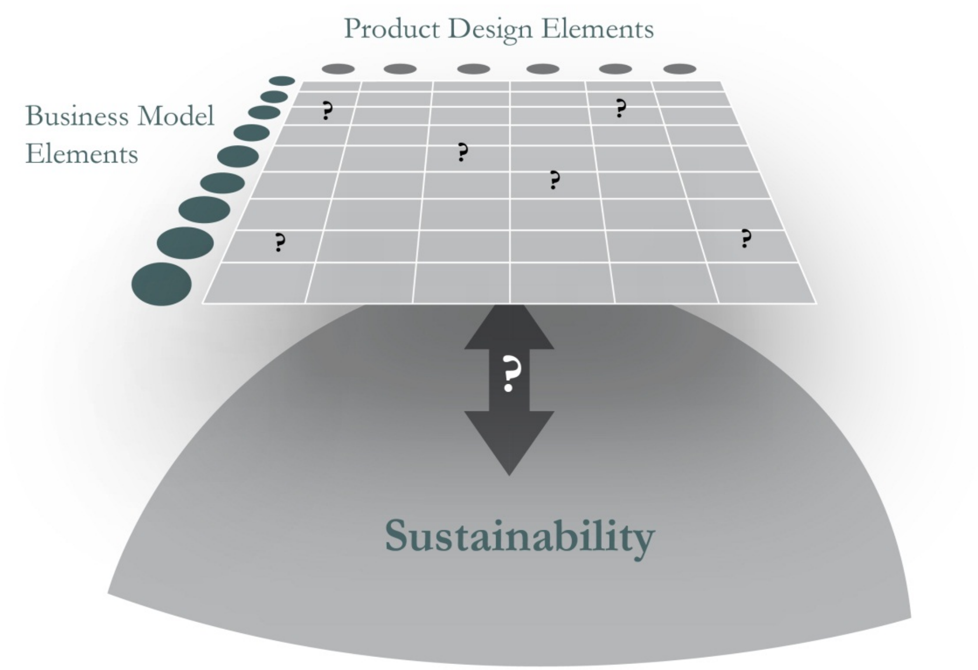


Figure 14: Analytical Process used to Isolate and Define Relationships

The nine building blocks of the companies' business model are defined using the theoretical framework developed by Osterwalder & Pigneur. Furthermore, the key product design aspects developed by the company are identified. Then, the relationship between each design aspect and each business model building block is defined (represented by the black question marks in Figure 14). The relationships are displayed in a matrix, with each relationship being described as a vital relationship, a significant relationship, or an incidental relationship. A relationship is vital when the existence of one side of the relationship is directly contingent on the existence of the other. Relationships are identified as significant where at least one side of the relationship significantly supports or affects the other side, but is not necessarily vital to its current embodiment. Lastly, incidental relationships are where one side is only one of many factors that support or affect the other side. Building blocks that have a negligible or non-existent relationship with a given innovation are not listed in each table. Following each sentence describing a given aspect of a relationship, the aspect is defined as either the business model supporting design (BMSD) or design supporting the business model (DSBM). The term "support" in this context is defined as "contributing to the success of" as defined in the Oxford English Dictionary ("support v. ", 1989). In the cases where one side isn't necessarily supporting the other, the relationship is defined as simply the business model affecting design (BMAD) or design affecting the business model (DABM). Lastly, the relationships that play a significant role in contributing to the environmental sustainability of the solution are identified.

It can be considered that the relationships that relate to sustainability, which is an emergent property of the system, in that any one given element of the system may not be inherently sustainable, but the system as a whole is sustainable, are between elements of the system and the system as a whole. This would mean that they are inter-hierarchal relationships (represented by the white question mark in Figure 14). The relationships between the business model and the product design aspects may be considered as relationships between elements, and thus on the same hierarchal level.

Finally, in the case study discussion, all the data is analysed in aggregation to provided analysis on a generalized level as well as on a particular level. This is known as using multiple levels of abstraction and considered an important quality of analysis in a successful qualitative research study (Creswell, 2007).

4.4 Limitations and Difficulties

There are numerous limitations of this research methodology. Primarily, the research looks at only three cases, so the results may not be able to be generalized or extrapolated to all cases. The results simply show what the relationships can be in some cases. Furthermore, the three cases studied are companies at different stages of their development. One is a long established company, one is a company in an early phase, and the third is just a concept. This means that the relationships, although accurate, are not all in the context of long term sustainability or profitability. Another limitation is that the case study of Better Place and Interface are based on the available information which can never be complete, given the outside perspective of the researcher of these competitive companies. It is possible to assume that if more information was made available, the data of the cases could be different, perhaps resulting in different interpretations. Lastly, all of the interpretation of the results is subjective based on the perspective of the researcher. Even the nature of the relationships is an interpretation of the researcher, given the information available. Despite the limitations and difficulties of the research, all measures were taken to ensure the most accurate results and the most reasonable conclusions drawn. The thorough information provided in each case is intended to make this research as transparent as possible. All interpretation is based on information that is presented, leaving others to interpret the facts in other ways, should they feel so inclined.

It should also be noted that in each case, there are relationships that exist between each of the aspects of product design. There are also many relationships that exist between each of the business model building blocks. This research, however, does not focus on such relationships. This research focuses solely on relationships that exist between an aspect of product design and a building block of the business model.

Chapter 5. Better Place Case Study

5.1 Introduction

After a successful career as a software industry executive (see Appendix 6: Shai Agassi's Background), Shai Agassi founded a company with the goal of accelerating the transition to sustainable transportation by making the electric vehicle (EV) as convenient and affordable as an internal combust engine (ICE) vehicle. The company, named Better Place, is doing this by building an EV ecosystem that integrates EVs, batteries that can be swapped out when depleted, a charging infrastructure, and smart grid software. By 2008, Agassi had two countries ready to adopt his solution, a partnership with a major automaker to produce his vehicles, and had amassed over $200 million in venture capital. Agassi had "launched the fifth-largest startup of all time in less than a year" (Roth, 2009).

Better Place offers a solution to a complex problem with numerous product innovations and an innovative business model. This case study looks closely at the relationship between product design and business model innovation at Better Place and attempts to answer certain questions helping to better understand this connection. It is hypothesized that innovators can exploit a better understanding of this relationship to find solutions to complex problems that could otherwise not be achieved.

The following sections describe Better Place's background and explicitly define the product innovations and business model of Better Place, breaking them down into six and nine key elements respectively. Looking at the intersections of these elements will help to identify the relationships, which are then analysed according to importance, level of support, direction, and sustainability.

5.2 Background

Energy demand and supply is often considered at the heart of the world's environmental problem. The extraction of energy from burning of fossil fuels was the cornerstone of the industrial revolution, and 250 years later, burning fossil fuels for energy is still the engine running the economy. The problem is that the CO_2 released into the atmosphere by burning fossil fuels has enormous health and environmental consequences and is contributing to raising the global average temperatures (Sangster, 2010). Looking at global energy supply (see Appendix 7: 2007 Global Energy Supply), most comes from oil (34%), more than either coal (27%) or natural gas (21%) (IEA, 2009). Further, the transportation sector accounts for over 60% of all oil consumption (see Appendix 8: 2007 Shares of World Oil Consumption) making the transportation sector a pretty tempting target for Agassi (IEA, 2009). Agassi calculated that by getting cars off oil and powered by electricity instead, world CO_2 emissions could be reduced by 20%. Taking the concept one step further, he realized that if he could pay a premium for renewable energy, eventually the price of renewably generated electricity would fall below the cost of coal-based electricity. Once that point was reached, no more coal plants would be built, reducing CO_2 emissions by another 40% (Roth, 2009). This was the level of impact that Agassi craved, but the automotive industry has already identified two major drawbacks to electric cars that seemed to make their ubiquitous adoption impossible: the range of any pure electric car is limited to only about a hundred miles, and recharging the battery takes hours not minutes. The automobile industry had decided the convenience that customers have come to expect from their ICE vehicles could not be matched by purely electric powered cars.

Any attempts by the major automakers to solve the electric car conundrum had focused on technology, but since the market for electric cars with their current limitations is so small, automakers haven't been able to generate the economies of scale needed to turn a profit selling them (Johnson, 2010). Using his background as a software designer, Agassi approached the problem not just from a technology perspective but also from the perspective of the needs of the customer. This is suggested as the first stage of any ecodesign project by Brezet and Carlolin van Hemel, where the focus is placed not on a physical product, but on the function of a product system and the way it fulfills a need (Brezet & Hemel, 1997). Mark Johnson and Alexander Osterwalder also place this approach at the center of business model innovation where the cornerstone is identifying the underlying-jobs to-be-done (Johnson, 2010). The needs-based starting point of both effective sustainable design and business model innovation denotes a fundamental commonality at the intersection of the disciplines. Agassi's analysis revealed numerous insights about the jobs-to-be-done by automobiles and the thinking that goes into purchasing a car. As he discussed in his presentation at the Brainstorm: GREEN conference in Pasadena, California in 2008, and as outlined in Mark Johnson's *Seizing the White Space: Business Model Innovation for Growth and Renewal* (2010), those insights were:

- Most consumers don't want to share a car; they demand independence and flexibility.
- Customers want their cars to be responsive and fun to drive, while being big enough to hold five people.
- Customers want their vehicles to be affordable to buy, own, and operate and to have a socially acceptable design.
- Customers don't want to refuel more than fifty times a year for more than 5 minutes each time.
- Customers are more concerned with the initial cost of purchasing a vehicle than the long term costs of ownership.
- Customers need to be able to live where they want, commute to work, and access recreation on the existing infrastructure of roads, with reliable refuelling and repair.
- Cars fulfill two distinct jobs: trips within a "transportation island" with a 20 mile radius in which they travel every day, and the occasional extended trip well beyond that distance.

(Johnson, 2010)

From these insights about the needs of his customer, Agassi clearly defined the parameters of his problem to solve. How Agassi defined the problem has a lot to do with the solution he came up with. Ultimately he framed his problem as, "How do you meet the jobs-to-be-done of personal transportation with renewably generated electricity?".

Agassi's biggest insight, in terms of finding a solution to the electric car conundrum, came from a meeting that he had with Bill Clinton. Clinton highlighted that the new car market was only 50 million new cars every year, whereas the used car market was 700 million cars annually. He suggested that if Agassi found a way to give away electric cars for free, Agassi could effectively make the resale value of any ICE vehicle zero, causing the electric car tipping point to happen overnight (Johnson, 2010). Agassi thought about how cell phone companies can give away cell phones when customers sign contracts to use their network services for a given period of time. He realized he could possibly subsidize the cars by focusing on selling miles the way wireless network providers sold minutes. Agassi started to see for the first time that, just like cell phones need a wireless network infrastructure to have value, electric cars only have value with an extensive charging infrastructure and smart-grid electricity network. Customers will need to plug in their cars in every parking spot, and that parking spot will need to know who that customer is and if they have already paid for the electricity they are about to use. Such an infrastructure would meet the needs of traveling within one's transportation island, but not meet the need of occasional extended trips. Agassi asked himself, "What if the battery was not considered part of the car but was part of the infrastructure?" If the infrastructure maintained ownership of the batteries, the electric vehicle infrastructure could include stations where depleted batteries could be quickly replaced with fully charged batteries, the way drivers currently stop at gas stations to turn an empty tank into a full one. By having drivers subscribe to monthly subscription plans providing "miles" from the charging network, Agassi could subsidize the cost of the car or even pay a premium to utilities to buy electricity generated from renewable sources, since the cost to propel a car one mile with electricity is 7 cents compared to 10-15 cents with gasoline (Johnson, 2010). In May 2007, with the goal of developing the world's first Electric Recharge Grid Operator or ERGO, Agassi founded the company, Better Place.

Better Place is a privately-held company based in Palo Alto, California. The slogan of the company reads "Accelerating the transition to sustainable transportation" (Better Place, 2011d). Agassi is adamant about not pushing electric cars on the market. He believes the market currently demands more sustainable transportation and he is just acting as a catalyst. Better Place is building a complete transportation ecosystem that is comprised of electric cars with swappable batteries; a network of charge stations that users can plug their cars into to charge their battery when they are parked at work or in a public parking space; battery swap stations so users can replace a depleted battery with a fully charged one in under 3 minutes; AutOS, an in-car operating system that informs users of the current status of the battery and the nearest available charge spot or swap station; and a smart-grid electricity infrastructure that distributes electricity optimally around the grid, depending on electricity demand and supply.

Better Place has already signed agreements with numerous countries preparing to roll out Better Place's EV ecosystem. Israel and Denmark are the first two countries where the Better Place infrastructure will go live, followed by Australia, the US (California and Hawaii) and Canada (southern Ontario). Better place is continuing discussions with other countries, with a particular interest in the Asian markets of Japan and parts of China (Meenakshisundaram & Shankar, 2010).

The Better Place ecosystem consists of numerous product innovations connected to an innovative business model, both of which are described in more detail in the following two sections.

5.3 Product Design at Better Place

5.3.1 The Renault Fluence Z.E.

In January, 2008, Better Place announced a deal with Renault-Nissan, wherein Renault-Nissan would develop an all-electric vehicle with compatible battery swapping technology for Better Place, called the Fluence Z.E. (Better Place, 2009). Today the Fluence Z.E. (Zero Emission) is the only car on the market that is officially designed for Better Place's ecosystem of charge spots and battery switch stations, however numerous other models are in development by both Renault-Nissan and the Chinese automaker, Chery[3].

Form Factor: In terms of the general design of the Renault Fluence Z.E., perhaps the most noteworthy aspect is that this car is a compact sedan, not a sub-compact hatchback such as the Nissan Leaf or Mitsubishi MiEV, the only other pure electric vehicles on the market manufactured by a major automaker. The car seats five full size adults and was designed to limit the compromises often associated with developing an electric vehicle, such as size and comfort. Considering that the Fluence Z.E is a tweaked version of the gasoline powered Renault Fluence, the car closely resembles most standard sedans. Introducing the electric motor did not have any effect on the form or styling of the car, however making the battery pack swappable did. For the battery to be swapped out quickly and easily, it needed to be placed behind the seat of the car, extending the total car length by 13 centimeters (Renault, 2010). This also reduced the usable trunk space from 529l to 300l. To create the illusion of a similarly proportioned rear end, the Fluence Z.E. has a glossy black strip on the front edge of the back hood, making the rear windscreen appear longer. Another noticeable difference can be found in the updated styling of the rear light clusters which feature a pattern of blue-hued lozenges, giving the rear end a more technological appearance. Lastly, the battery charge flaps are located behind the front wheel on both the right and left hand side of the car, whereas the gas model has only a gas intake on the right side of the car.

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[3] Better Place does have a small fleet of Nissan Rogue automobiles that have been converted into electric vehicles with swappable batteries for use as taxis in Tokyo, but there are no concrete plans to have the vehicles mass produced.

Figure 15: Renault Fluence Z.E. (Better Place, 2011c)

Motor: The Fluence Z.E. is propelled by a synchronous electric motor with a rotor coil (see Appendix 9: Details of the Fluence Z.E. Electric Motor). This type of electric motor, as opposed to an induction electric motor, makes maximum torque available from very early on in the acceleration. The motor also acts as a generator converting kinetic energy into electricity during deceleration, which is then transferred to the battery for storage.

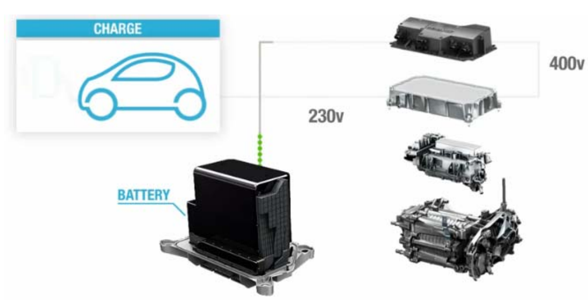

Figure 16: Image of the Fluence Z.E. Electric Motor (Screen capture from Renault, 2011a)

Battery: The battery that powers the Fluence Z.E. is a 22kW/h lithium-ion battery and is located just behind the rear seats. It is the first electric car battery to be designed to be swapped out, and has numerous features that facilitate the battery swapping procedure such as its vertical stack configuration, as can be seen in Figure 17. The battery is placed just behind the rear seats and because of its weight of 250 lbs which is not present in the gasoline powered Fluence, the Fluence Z.E. has extremely stiff rear suspension.

Figure 17: Fluence Z.E. Battery Placement and Configuration (Screen capture from Renault, 2011a)

The battery can be recharged in six to eight hours through a 220v current, common in almost every household. The vast majority of Better Place charge spots will provide a 220v current, but the battery can also be charged directly by a 400v current, which cuts charge time down to only 30 minutes (Renault, 2010). This option will only be available in some charge spots in 2012 or 2013. The last option for recharging is swapping the battery out at a swap station, which is by far the fastest option, taking only three to five minutes.

Onboard Computer and AutOS Software: The software developed by Better Place is the underlying intelligence that connects the nodes of the Better Place ecosystem. Drivers, batteries, charge spots, swap stations, and utility companies are all connected through Better Place's electric vehicle infrastructure software. The user end of the software, installed on all cars operating within the Better Place charging network, is called AutOS and runs on a full onboard personal computer (Better Place, 2011b). The software's primary functions include *energy monitoring*, knowing and informing the driver of the battery charge level; *energy planning,* communicating range and selecting routes based on infrastructure availability; *service and support,* directions to charging infrastructure and live troubleshooting; and *charging and battery switch,* managing the battery swap process and priority charging. Priority charging is one of the most valuable functions of Better Place's infrastructure software. Agassi told Associated Free Press reporter Gavin Rabinowitz that the infrastructure software is designed to manage the recharging of EV's "without the addition of a single generator or transmission line" (Rabinowitz, 2011). Sidney Goodman, Better Place's vice president for automotive alliances, explains how the software curbs demand, keeping it below existing grid maximum demand levels through the example of 1,000 people arriving for work simultaneously, " 'The system will know that I had a five-minute drive to work and that I'm in the office from 8 to 6, so it will not start charging me until later in the day (…) but it'll know Julie drove a half hour to get to work and might have drained her battery, so it'll charge her faster' " (Woody, 2009). Ultimately, most EVs are expected to be charging at night when grid demand levels are the lowest (Andersen, Mathews, & Rask, 2009). The image below depicts a screenshot from the AutOS software:

Figure 18: AutoOS Screen Capture (Better Place, 2011b)

5.3.2 The Infrastructure

Charge Spots: A key element in the wide adoption of electric cars is the ability for owners to plug their cars in for recharging wherever they will be parking: at home, at work, and in public parking spots such as at shopping malls and on the street. Unlike the electric cars which are designed and built by Renault, one of Better Place's strategic partners, the charge spot network is developed and deployed by Better Place itself. In the pilot country of Israel, Better Place is installing over 500,000 charge spots, which amounts to 2.5 charge spots for every car on the road, and at a cost of between $50 and $100 million dollars, the charge spot network is the primary use of Better Place's raised capital (Andersen et al., 2009). At such volumes, minimizing charge spot costs is clearly one of Better Place's top priorities. Agassi describes how the integrated design strategy of having the cars and charge spots designed to work together, helped minimize costs:

> We designed charge spots that are not stuffed full of computer equipment and instead put the computational and network power into the cars themselves and into a network management hub. A consumer would flash a card at the charge

> spot, which would communicate with the on-board computer system, telling the charge spot to start charging based on the consumer's usage plan. This would let us build cheaper charge spots than in other models that build network software and credit-card reading mechanisms into every spot. (Agassi, 2009, p. 135)

To design the charge spots, Better Place commissioned San Francisco based New Deal Design (NDD). NDD founder, Gadi Amit, assembled a charge spot team from his team of twelve designers, more familiar with designing personal electronics than infrastructure. This background proved to be useful. Original electric car chargers were modeled after the gasoline pump form factor with a power cord in place of the hose. NDD was inspired by a different model: chargers for portable electronics such as laptops, cellphones, and iPods (Wong, 2009). As a result, the power cord will be kept in the owner's car and will connect the charge spot to the car outlet when charging is required. The saved space of not having the cord in the charge spot means that two cars can be charged simultaneously at one charge spot, essentially cutting costs in half. Furthermore, as explained by Joe Paluska, Better Place's chief marketing officer to Vanessa Wong of Bloomberg Businessweek, the NDD team "removed hinges and doors from the first prototypes, simplified the display screen, and changed some internal components, reducing cost to about one-tenth of earlier designs" (Paluska as told to Wong, 2009). NDD's final design can be seen in Figure 19 below.

Figure 19: Charge Spot Designed by New Deal Design (Better Place, 2011e)

Key design features of the charge spot include the concrete base that interfaces effectively with any material in which it may be installed, the easily recognizable blue cap so drivers can easily see the available charging spots from their vehicle, a peaked top surface to direct rain and snow off the surface to the ground, and two LED icons on the top surface that indicate the readiness of the charge spot. While the base is concrete, the exterior material of the shaft is steel, capable of withstanding the impact from a car, and the blue cap is a high-impact plastic (G. Amit, 2011b). Using the charge spot consists of 5 steps:

- The user chooses a parking space equipped with a charge spot.
- She connects the power cord to both her car outlet, and the outlet on the charge spot.
- She flashes her identification card over the better place icon.
- Charging begins when the user has been identified as a subscribing member.
- An update on charging status is sent via text message to the user's phone.

Swap Stations: Battery swap stations are the cornerstone of the Better Place model in that they are what can make the electric car as convenient as combustion engine cars. Better place suggests that battery switch stations essentially make possible the unlimited range electric vehicle. The batteries in the electric cars that work with the Better Place ecosystem have a range of about 160km, but according to Better Place's research, 80% of users do not drive more than 100 km in their daily routine, and on average, people only drive more than 160km continuously five times per year. Better Place believes that users will be charging their vehicles primarily at home, but the swap stations are for those extenuating circumstances when a fully charged battery is needed immediately (see Figure 20).

Figure 20: Images of the Better Place Swap Station (Better Place, 2011a)

Using the swap station consists of 6 steps (see Appendix 10: Storyboard of the Swap Station Use Scenario):

- AutOS notifies the user of the closest swap station when the battery charge is low.
- The driver engages the car on a track similar to those at an automatic car wash.
- A mechanism under the car dislocates the depleted battery, which is lowered out of the vehicle on a hydraulic platform.
- A rotating tray replaces the depleted battery on the platform with a recharged one.
- The hydraulic platform raises the charged battery into the car where it is secured into place.
- The driver can then drive away without the need to leave the car for either the swapping procedure or for payment.

5.4 Better Place's Business Model

It is easy to look at Better Place's business model as one of its key innovations. The way that the company is set up to operate is completely unique among other companies playing in the electric vehicle market. It also has been considered the catalyst that may make electric vehicle adoption possible (Andersen et al., 2009; Enriettia & Patruccoa, 2009). The business model can be described in multiple ways and perhaps can be distilled down to three key elements:

> There are three basic elements to the EV rechargeable grid business model, or what Agassi refers to as the Electric Recharge Grid Operator (ERGO) model. (…) There is (1) an infrastructure of an intelligent rechargeable grid connected via the Internet; (2) partnerships with vehicle and battery manufacturers as well as with suppliers of network hardware; and (3) a means of reducing costs for consumers in taking up the EV option, by offering consumer's batteries (and even cars) on a leasing arrangement, where fees vary with mileage driven. (Andersen, Mathews, & Rask, 2009, p. 2482)

Recognising the principal elements of the business model is important, but to get a comprehensive understanding of Better Place's business model it is necessary to define all of its elements. The business model canvas framework developed by Alexander Osterwalder and Yves Pigneur (Osterwalder & Pigneur, 2009) will be used as the theoretical framework to define Better Place's business model (see Figure 21). The following paragraphs will define each of the nine building blocks of Better Place's business model canvas.

<table>
<tr>
<td rowspan="2">Key Partners
Automobile Manufacturers, Battery Manufacturers, Energy Companies, Governments.</td>
<td>Key Activities
Managing and maintaining infrastructure.</td>
<td rowspan="2">Value Proposition
Convenient and affordable electric vehicles through access to a charging infrastructure service and battery leasing.</td>
<td>Customer Relationship
Customer acquisition, Seamless user experience.</td>
<td rowspan="2">Customer Segments
Mass Market.</td>
</tr>
<tr>
<td>Key Resources
Charging infrastructure and batteries.</td>
<td>Channels
Better Place Sales Center,
Renault Dealerships.</td>
</tr>
<tr>
<td colspan="3">Cost Structure
High infrastructure costs, high margins on electricity.</td>
<td colspan="2">Revenue Streams
Subscription to infrastructure and battery leasing.</td>
</tr>
</table>

Figure 21: Business Model Canvas for Better Place

Customer Value Proposition: Better Place's customer value proposition is very simple. The offering is essentially electric powered personal and fleet transportation with the same affordability and convenience as ICE vehicles. The offering also includes the service of access to a recharge network of charge stations and battery swap stations.

Customer Relationship: Since Better Place is a new company, the customer relationship is based on customer acquisition with the primary customer relationship goal of signing up new subscribers to the network. A secondary goal of the customer relationship is making all aspects of the customer's transportation experience feel seamlessly integrated through hardware, software and dedicated personal assistance.

Channel: The two channels that Better Place uses to reach customers are Better Place Visitor and Sales centers, where customers can come to understand the Better Place business model, test drive vehicles, charge spots and swap stations, purchase the vehicles, and subscribe to the recharge network services. The other channel is through Renault dealerships, where Better Place sales people sell the swappable battery vehicles and recharge subscription plans. Israel will primarily use Better Place sales centers and Denmark will mainly use the Renault dealerships. Distribution channels in other countries have not yet been developed.

Customer Segment: Better Place's market is the mass market. The driver behind developing this model was to find a way to make the electric vehicle desirable to all drivers including short distance and long distance drivers, younger and older customers, singles, couples, families, and companies with commercial fleets.

Key Partners: Better Place's key partners are one of the cornerstones of the Better Place business model. Better place has partnerships with Renault Nissan for electric car manufacturing and NEC for battery manufacturing. Better Place signed a Memorandum of Understanding in January 2008 with both companies to build the required products, while Better Place focused on the recharge network (Andersen et al., 2009). More recently, a large step was taken to partner automobile and battery manufacturers, by creating a consortium called EASYBAT to enable the development of standardized parts and procedures for swappable batteries.

Better place also has partnerships with governments and energy companies in every country in which it plans to operate. Governments are instrumental partners, considering that many of the charge spots are installed on public land, and even more importantly, because partner governments have placed taxes on ICE vehicles and offered subsidies for electric vehicles. Energy companies are also key partners because Better Place plans to be able to return electricity back into the grid during periods of peak demand, and also because of Better Place's plan to transition the electricity it purchases to renewably produced electricity. Solar and wind power are intermittent but electric grids have remarkably little storage capacity. Better Place plans to partner with renewable energy companies to help solve this problem.

> Wind is often at its most productive at night, but demand at night is often low. Combining EV batteries with the network-management software, all the excess electricity generated by wind power by night (or solar power by day) can be stored in EV batteries during non-peak usage times late at night and used as a buffer on the network. This solves a previously tricky problem in making renewable sources effective. (Agassi, 2009, p. 136)

For example, DONG Energy is a key partner in Denmark since it produces wind powered electricity on a massive scale. DONG Energy has a large surplus of electricity at night and is faced with the prospect of developing very expensive and inefficient electricity storage solutions. Since most customers plug their electric cars in at night, DONG Energy is willing to discount its electricity to power the nation's electric cars, instead of having to store the electricity itself.

Partnerships are so vital to the Better Place business model that it has taken on the characteristics of what is known as an innovation platform. Since the introduction of electric vehicles combines the goals and resources of many industries, a model such as Better Place's acts as an innovation platform by helping "the integration, coordination and direction of the different strategies and goals of various organizations" (Enriettia & Patruccoa, 2009).

Key Resources: Better Place's key resource is its charging infrastructure which is made up of three elements. The first is the network of charge spots that are deployed in homes, offices, and public parking spots - wherever a customer could be parking their electric car. The second is the network of swap stations and electric batteries that Better Place has installed. The batteries and swap stations are what extend the range of electric cars indefinitely. The third element is the network software that Better Place has developed that allows it to manage all aspects of its smart grid.

Key Activities: Better Place's key activities are managing the network of swap stations, charge spots, and infrastructure software. The swap stations need to be maintained and kept fully functional, the charge sports need to be repaired and upgraded when necessary, and the network software will need to be continuously upgraded and streamlined.

Cost Structure: Infrastructure development is the primary cost of this business model. Value offered to the customer lies in the ubiquity of the charge spots, so the charging infrastructure must be fully deployed before the first car is sold. The charge spots in Israel alone were estimated at "between $50 and $100 million - making this the target of initial capital raising efforts" (Andersen et al., 2009, p. 2482).

Given the high cost of the infrastructure, the margin in the Better Place business model lies in the fact that electricity is cheaper than gasoline. "It costs roughly 16 cents a mile to operate an ICE car and 8 cents a mile to operate an EV. When battery prices fall and clean energy is cheaper because it is produced at scale, the operating cost of an EV should be four cents a mile by 2015 and two cents a mile in 2020" (Agassi, 2009, p. 135). By charging per mile rates equivalent to ICE rates, Better Place can use the margin to recuperate its high infrastructure costs. In terms of key fixed and variable costs, the infrastructure development, deployment, and management are key fixed costs. The one key variable cost is the electricity that will be used to recharge the electric vehicles of the subscribers.

Revenue Streams: Better place revenue streams come in the form of mile subscriptions. A subscriber chooses from a plan that gives them access to a certain number of miles per month, much like a cellphone subscriber pays for minutes every month. For a lower monthly rate, customers get the charging equivalent to a lower number of miles whereas higher paying customers can choose an unlimited mile charging plan. Also included in the monthly rate is the cost of leasing the battery.

5.5 The Product Design and Business Model Relationships at Better Place

The following six tables systematically identify the relationships that exist between product design and the business model at Better Place. Each table represents a particular aspect of product design and the building blocks of the business model with which the design aspect has a noteworthy relationship. Building blocks that have a vital relationship with that aspect are highlighted in the darkest green. Relationships identified as significant are highlighted by the middle green. Lastly, incidental relationships where one side is only one of many factors that support or affect the other side are highlighted in the lightest green. Building blocks that have a negligible or non-existent relationship with a given innovation are not listed in each table. Following each sentence describing a given aspect of a relationship, the aspect is defined as either the business model supporting design (BMSD) or design supporting the business model (DSBM). In the cases where one side isn't necessarily supporting the other, the relationship is defined as simply the business model affecting design (BMAD) or design affecting the business model (DABM).

	EV Form Factor
Key Partners	Better Place's partnership with Nissan-Renault was **essential** in developing the Fluence Z.E. (BMSD)
CVP	The fact that the EV competes in the full size sedan category as opposed to the sub-compact category (such as the Nissan Leaf and the Mitsubishi Mi-EV) is **central** to the CVP. (DSBM) (BMAD)
Customer Segment	The size, styling and function of the EV are **central** in targeting as broad a target market as possible. (BMAD) (DSBM)
Key Resources	The swappable batteries, a key resource of the Better Place business model, **significantly affected** the car form factor by making it 13 cm longer and by reducing trunk space by 129l. (BMAD) The battery placement also required a very stiff rear suspension. (BMAD) Furthermore, to facilitate plugging in to the charge spots, another key resource, a battery charge plug is located on both sides of the car. (DSBM) (BMAD)
Customer Relationship	The styling of the car and overall appeal **contributes** to signing up new customers. (DSBM)

Table I: EV Form Factor / Business Model Relationships

	Electric Motor
CVP	The electric motor is a **vital** component of the customer value proposition by providing a more environmentally friendly alternative to the ICE. (DSBM) (BMAD) Its ability to generate electricity during breaking also **contributes** to the EV'S energy efficiency. (DSBM) Lastly, EV's have roughly half the number of moving parts than their gasoline counterparts, which **adds** value to the customer by making lifetime ownership costs lower by comparison. (DSBM)
Key Resources	Better Place's key resources (charge spots, swap stations and swappable batteries) all exist as a means to increase the convenience of using an electric motor. (BMSD) The electric motor is **vital** to the existence of the Better Place's key resources. (DABM)
Key Partners	Better Place's partner, Renault-Nissan, was **vital** in developing a car powered by an electric motor. (BMSD) The electric motor and its associated benefits is the one **central** reason that governments are willing to work alongside Better Place. (DSBM) The inclusion of a charger in the electric motor takes a 230V current instead of a 400V current **significantly** reduces likelihood of overtaxing the grid and helps appease the fears of the electric utility partners. (DSBM)
Customer Relationship	The draw of a car powered by an electric motor and the associated difference in driving feel (immediately available torque and rapid acceleration) **contributes** to the acquisition of new customers. (DSBM) The inclusion of a charger that converts a 230V current to the required 400V current helps to make the vehicle easily charged at home, **significantly increasing** overall appeal. (DSBM)

Table II: Electric Motor / Business Model Relationship

	Onboard Computer and AutOS Software
Key Resources	AutOS is **vital** to the customer's ability to interface with the charging infrastructure. It is a direct function of the charging infrastructure, the key resource of the Better Place business model. (BMAD) (DSBM) Furthermore, including this software in the car prevents the charge spots from all requiring expensive integrated networking hardware which **significantly** lowers the cost of the charge spot network. (DSBM)
Key Partners	Having a partnership with Renault Nissan is **vital** to having Better Place's onboard computer and AutOS installed in every car. (BMSD) The ability for AutOS to communicate with the grid and electricity utilities **contributes** to a worthwhile partnership with the electric utilities. (DSBM) The participation of the electricity utilities **contributes** to AutOS' intelligence helping to pass on energy price reductions to customers. (BMSD)
Customer Relationship	AutOS plays a **key role** in making the Better Place ecosystem feel well integrated and to keep Better Place in close communication with its subscribers. (DSBM)
CVP	AutOS **contributes** to the ease of use and experience of the charging infrastructure service, part of the customer value proposition. (DSBM)

Table III: Onboard Computer and AutOS Software / Business Model Relationship

	Swappable Battery
CVP	The swappable battery is **vital** to the offering of an EV with the same affordability and convenience as an ICE vehicle, since without it, EV range is only 160km. (DSBM) (BMAD)
Revenue Structure	The leasing model for the battery is **vital** in Better Place's battery switch model. If the battery was owned by the customer, it could not be switched out when depleted. (BMSD)
Key Resources	Swap stations, one of Better Place's key resources, interface directly with the swappable batteries in the EV's and both are **vital** to Better Place's business model. (DSBM) Standardizing swappable batteries will **significantly contribute** to smoother and more reliable battery swapping experiences. (DSBM)
Key Partners	A partnership with NEC was **vital** in developing the swappable battery. A new partnership, the EASYBAT consortium, will be instrumental in standardizing parts and procedures for swappable batteries. (BMSD)
Customer Segment	The swappable battery is what extends the range of an EV beyond the usual 160km, **significantly increasing** the EV appeal to the mass market. (DSBM)
Channel	The new practice of using swappable batteries has **contributed** to the creation of visitor centers, a sales channel where potential subscribers can come to test out the vehicles, charge spots, and swap stations. (DABM)
Key Activities	Managing the network of swap stations which go hand-in-hand with the swappable batteries is one of numerous key activities for Better Place. (DABM)
Cost Structure	The swappable battery inventory owned by Better Place **contributes** to high capital costs which are offset by high margins in powering cars with electricity. (DABM) Minimizing swappable battery costs can **help reduce** high capital cost structure. (DSBM)
Customer Relationship	The convenience the swappable battery affords and its ability to be charged quickly **contribute** to increasing customer acquisition. (DSBM)

Table IV: Swappable Battery / Business Model Relationships

	Charge Spot
CVP	The charge spot network is **vital** to making EV's convenient by allowing subscribers to charge their vehicles wherever they may be parking. (BMAD) Charge spot ubiquity and overall ease of use increase value to the subscriber. (DSBM)
Revenue Streams	Revenues collected for subscription to the charge spot network are **essential** to Better Place's revenue streams and pay for the high initial capital investment. (DSBM)
Key Resources	The charge spot network is one of Better Place's key resources. As a key resource, swap stations are **vital** to the Better Place business model. (DSBM)
Key Activities	Managing the network of charge spots is a key activity in Better Place's business model. (BMSD) Reliability, efficiency, and usability **significantly facilitate** Better Place's key activities. (DSBM)
Cost Structure	Cost cutting measures taken to make the charge spot affordable such as a simple interface, minimal moving parts, and designing it to be quickly deployable, **significantly reduces** the high capital investment in infrastructure. (DSBM)
Key Partners	Charge spot design is **key** to getting municipal and federal government partnerships and must meet municipal building codes since most charge spots are deployed on public land. (DSBM) Also, having a partnership with the automobile manufacturer means that the power cord that a subscriber would use to connect to the charge spot can be sold with and stored in the EV. Eliminating the cord from the charge spot freed up enough space so that one charge spot can power two EVs. (BMSD)
Channel	The new practice of using charge spots has **contributed** to the creation of visitor centers, a sales channel where potential subscribers can come to test out the vehicles, charge spots, and swap stations. (DABM)
Customer Segment	Ergonomics and overall ease of use will **help** to target a very wide segment of the population. (DSBM)
Customer Relationship	Added convenience provided by the charge spots will **increase** demand for electric cars. (DSBM)

Table V: Charge Spot / Business Model Relationships

	Swap station
CVP	Swap stations are **vital** to making EV's convenient, extending range beyond 160km without having to wait for a recharging. (DSBM) (BMAD)
Revenue Streams	Revenues collected for subscription to the swap station network are **essential** to Better Place's revenue streams and pay for the high initial capital investment. (DSBM) Also, the leasing model for swappable batteries is **vital** to having switch stations, letting subscribers part ways with the battery at the swap station. (BMSD)
Key Resources	The swap station exists due to another one of the key resources, the swappable battery. (BMAD) The swap station network is one of Better Place's key resources which is **vital** to the Better Place business model. (DSBM)
Key Activities	Managing the network of swap stations is a key activity in Better Place's business model. (BMSD) Reliability, efficiency and usability are **crucial** in facilitating Better Place's key activities. (DSBM)
Cost Structure	Cost cutting measures taken to make the swap station affordable, such as a simple design with minimal moving parts, **significantly reduces** the high capital investment in infrastructure. (DSBM)
Channel	The new practice of using swap stations has also **contributed** to the creation of visitor centers, a sales channel where potential subscribers can come to test out the vehicles, charge spots, and swap stations. (DABM)
Customer Segment	Overall ease of use will **help** to target a very wide segment of the population. (DSBM)
Customer Relationship	Added convenience provided by the swap stations will **increase** demand for electric cars. (DSBM)

Table VI: Swap Station / Business Model Relationships

5.6 Results and Interpretation

After looking through the tables that identify the many relationships between aspects of Better Place's product design and Better Place's business model, the following results can be noted. Of the 54 possible relationships that could come from looking at how each of the 6 main aspects of Better Place product design relates to each of the 9 building blocks of the Better Place business model, 39 relationships were identified. Of those 39 relationships, 16 are identified as vital relationships, whereby the existence of one side of the relationship is directly contingent on the existence of the other; 8 are identified as significant relationships, where at least one side of the relationship significantly supports or affects the other side but is not necessarily vital to its current embodiment; and 15 incidental relationships, where one side is only one of many factors that support or affect the other side.

Furthermore, within those 39 relationships, there are 37 instances where design supports the business model (DSBM); 11 instances where the business model supports design (BMSD); 6 instances where design affects the business model (DABM); and 10 instances where the business model affects design (BMAD). These instances add up to 64 since many of the 39 relationships are multifaceted. Table VII summarizes where the relationships exist and denotes the level of significance of each relationship.

		Aspects of Product Design					
		Electric Vehicle				Infrastructure	
		Form Factor	Comp / AutOS	Electric Motor	Swappable Battery	Charge Spot	Switch Station
Business Model Building Blocks	CVP						
	Customer Relationship						
	Channel						
	Customer Segment						
	Key Partners						
	Key Resources						
	Key Activities						
	Cost Structure						
	Revenue Streams						

Table VII: Significance Level of Product Design and Business Model Relationships at Better Place

A first look at the results paints a clear picture of a very interdependent relationship between product innovation and the business model at Better Place. There are a lot of relationships that have been identified, defined and categorized. Taking a closer look at these results will help to draw some more detailed conclusions.

To interpret the results, one can consider the first layer of data representing the strength of the identified relationships. The fact that there is at least a minor relationship in 39 of a possible 54 cells suggests that product innovation is highly interconnected with the business model. Moreover, identifying 16 of these 39 relationships as being vital where one side's existence is contingent on the other, suggests an extremely high level of interdependence, especially since in those 16 relationships, 4 are the design being contingent on the business model, 3 are the business model being contingent on a design innovation, and 9 are reciprocal.

In some cases, such as in the ways that all of the design innovations are related to the customer value proposition (CVP), the relationship is reciprocal because the customer value proposition of environmentally friendly personal transportation is what led to the creation of these design innovations in the first place. Simultaneously though, all these design innovations work together to create that value proposition and the better designed they are, the better the customer value proposition they create. It is safe to say that in almost any context, there will be a reciprocal relationship between product design and the CVP since the CVP will always inform aspects of product design, and the success of the design will in turn support the CVP.

In this case, however, there are vital relationships that are not as generic as the previous example. The innovation that can be considered the catalyst to the development of this whole EV ecosystem is the revenue stream innovation of separating the ownership of the car from the ownership of the battery. This breakthrough not only lowers the initial price of the EV to be in line with competing ICE vehicles, it makes the whole battery swapping concept possible, since a customer would never want to trade out a battery she owns for one that may be more heavily used or even damaged. This is a clear example of how a product innovation, the swappable battery, is made possible by changing a revenue stream from battery sale to battery lease.

Another vital relationship where the business model supports product innovation that is worth noting is the role that partnerships have played developing the EV and the swappable batteries. Partnering with outside companies to develop product innovations helped Better Place focus on developing its key resource, the charging infrastructure and the associated software. Using the partnership aspect of the business model to link the car developer, the swappable battery developer, and itself, the infrastructure developer, Better Place found the best way to create a fully integrated system with all parts designed to work together (in the same sense as Apple's iPod + iTunes ecosystem). Advantages of this integrated approach are numerous. Partnering with car manufacturers means that Better Place can have powerful computing hardware running its own software, AutOS, in each vehicle. In turn, this interface helps subscribers use the network efficiently, and as a bonus, lowers per unit cost of the charge spots by eliminating the need for each charge spot to house the expensive hardware and software. Furthermore, this partnership solves problems related to the power cord in the charge spot. All other companies developing charge spots for EV's include the power cord in the charge spot, which uses valuable space, and contributes to each charge spot being designed to charge only one car. Because of its business model approach and partnerships, Better Place can have the cords stay in the car and belong to the user (who takes better care of the cord) freeing up space in the charge spot so it can charge two EVs simultaneously (G. Amit, 2011b). Partnering with the battery manufacturers also supports design innovation. By coordinating swappable battery design with both the EV manufacturer and Better Place's own swap stations, Better Place has been able to solve complex engineering problems related to battery swapping that some critiques argued could not be solved.

The third noteworthy example of a vital relationship where the business model supports product innovation is the creation of Better Place's charging infrastructure to support the product innovation of powering a vehicle with an electric motor. The infrastructure and the related software that Better Place has developed, and charges its subscribers to access, is what was needed to give the EV a chance to compete with the ICE vehicle on convenience. Otherwise, the EV was destined to remain a viable option for a niche market only. Using the key resources building block of the business model to support a design innovation, Better Place stands to leapfrog companies that were addressing the EV convenience problem from a technological perspective only.

Looking at the second layer of data, the multiple aspects of each relationship and the directions in which the influences are focused reveal some interesting conclusions. By far the most common relationship is where design supports the business model. This is probably due to the many ways that elements of product development can support the business model, such as by contributing to the CVP, creating revenue streams, minimizing costs, improving the relationship with the customer, helping to target the customer segment, helping to meet the needs of partners, minimizing required key resources, and facilitating key activities.

One of the most significant ways that design supports the business model in the Better Place ecosystem is how each of the design innovations work together seamlessly to make the CVP of convenient and affordable EVs possible. The fact that the Fluence Z.E. competes in the full size sedan category, as opposed to the sub-compact category, greatly adds to the convenience of Better Place's offering. Furthermore, AutOS plays a key role in making the Better Place ecosystem feel well integrated which supports the CVP and keeps Better Place in close communication with its subscribers, improving its relationship with its customers. Lastly, the electric motor, rechargeable batteries, charge spots and swap stations combine to replace the gasoline powered vehicle paradigm with a convenient and affordable alternative.

Another way that product design supports the business model is through the revenues that Better Place collects from charging its customers to access the charge spots and swap stations. These products are the reason that Better Place can collect revenues. Additionally, the better designed these products are in terms of functionality, usability, and ergonomics, the more customers will be willing to pay to have access to them. Considering that a large part of Better Place's revenues comes from these subscription fees, successful design stands to play a key role in supporting a steady revenue stream for the company.

One more building block that is supported by product design at Better Place is the cost structure. One of the defining features of the high-capital-cost cost structure is the infrastructure that needs to be built, but all of the cost cutting design solutions support minimizing capital costs. For example, the charge spots with a simple interface, minimal moving parts, that are quickly and easily deployable, significantly reduce the high capital investment in infrastructure.

As a last level of interpretation, it is important to take a close look at where the relationships highlighted through the analysis intersect with sustainability. One of the questions on which this research seeks to shed light, is whether a better understanding of the relationship between product design and business model innovation can help to create more sustainable solutions. Looking at where these relationships helped to create a more sustainable solution will underscore the potential environmental benefits of approaching problem solving from both a business model innovation and product design perspective simultaneously.

On a fundamental level, Better Place can be considered a company that seeks to shift the personal transportation paradigm from one that is run on oil, to one that is run on renewable electricity. Any elements that support the long term success of Better Place in this mission is either directly, or at least indirectly, contributing to a more sustainable future. With respect to the relationships between product innovation and the business model at Better Place, some of the 39 identified relationships stand out as being key to increasing the environmental benefits of the Better Place solution.

The Better Place business model "takes perhaps its boldest leap in separating the concept of ownership of car from ownership of battery" (Andersen et al., 2009, p. 2483). As detailed above, this leap is what makes the swappable battery possible. This relationship at the intersection of the revenue stream and the swappable battery is one of the keys to the sustainability of Better Place's business solution because it makes the swappable battery possible, and the swappable battery is what makes Better Place's EV a viable alternative to the ICE vehicle. The inability to go more than 160 km without spending numerous hours waiting for a battery charging is what has led other companies, such as GM with its plug-in Electric Volt, to sell EVs with range extending ICEs that are engaged when the battery is depleted. The fact that with a swappable battery, a pure EV can meet drivers' needs in both the transportation island and on extended trips, suggests that the intersection between the swappable battery and the CVP is another key sustainability relationship.

An additional significant sustainability relationship is at the intersection between the key partners building block and the onboard computer system with AutOS. Two key partners that augment sustainability for Better Place are the government partnerships that provide subsidies for fuel efficient cars and taxes on ICE vehicles, and the electric utilities that can possibly provide renewable electricity. Better Place's infrastructure software and AutOS help to balance electricity demand with the naturally fluctuating supply of renewable energy, "creating a market for co-ordinated production and consumption of renewable energy" (Andersen et al., 2009, p. 2485).

The last sustainability relationship worth noting is the intersection between the cost structure and the electric motor. That two fold reduction in cost of powering a vehicle with electricity, as opposed to gas, is where Better Place will look to find a margin needed to pay itself back for it's expensive infrastructure cost. But this margin is also where Better Place can find money to pay a premium for renewable electricity, encouraging utilities to increase renewable electricity supply (Roth, 2009). As supply and demand increase for clean electricity, economies of scale help to bring renewably generated electricity closer to price parity with the other energy sources.

5.7 Better Place Case Conclusion

Studying Better Place has proven to be a very valuable exercise in understanding the relationships that can exist between product design and business model innovation in the context of a sustainable organization. In general, the battery leasing model, the key partnerships and the charging infrastructure stand out as key innovations in the Better Place business model, and yet most of the business model and product designs are highly related and interdependent. They combine to create a potential solution to the environmental problems of the current gasoline powered personal transportation paradigm with the additional benefit of conceivably catalyzing the rapid growth of the renewable energy industry. As described by Anderson et al:

> The innovative contribution of the model rests in its ability to combine two problems and thereby solve each of them. One problem is focused on reducing CO_2 emissions from the private transport sector, where a large part of the GHG emissions problem arises. The second problem involves utilizing an increased range of renewable energy sources into electric power grids and managing the fluctuations in supply (as witnessed in the Danish case with wind energy). (Andersen et al., 2009, p. 2485)

Given the interdependent relationship of the business model and product design at Better Place, there are multiple instances where product design supports the business model. The revenue structure of leasing the battery supports product design by creating a context where designing a swappable battery could be possible. The Partnership that Better Place created with Renault was vital to the design of Better Place's electric car and allowed Better Place to focus on designing the infrastructure. Lastly, the charging infrastructure, a key resource in Better Place's business model, is key to solving many design problems associated with EVs. The business model also supports product design at Better Place. The way product design is treated holistically at Better Place, so that all products integrate with each other seamlessly, greatly supports the CVP of convenient and affordable EVs. Good product design makes emotional connections, better meets users' needs and this inevitably translates to supporting the revenue stream. Lastly, since Better Place's cost structure is defined by high capital costs, design solutions that minimize cost greatly support Better Place's cost structure.

Better Place is still in its early stages, however, and its long term viability as a sustainable transportation solution or profitable company is by no means guaranteed. There are still numerous unknowns considering that as of publishing, Better Place is just starting to pre-sell automobiles in Israel and Denmark. How customers will respond to using the charging infrastructure, how reliable the software will be, and how much more or less convenient the EVs actually turn out to be are still unproven in large scale practice. Some critics doubt whether the electric grid will be able to handle the additional demand, saying that, "The myth that thousands of EVs will seamlessly fold into the power grid by charging at night, using otherwise idle generating plants and power grids, is breaking down" (Fairley, 2010). Also, others suggest that the transition to swappable batteries could be more difficult than Better Place expects. As reported by Clive Thompson of the New York Times, Sue Cischke, Ford's group vice president for Sustainability, Environment and Safety Engineering, worries that swappable batteries "require carmakers to all agree to design cars around one standard-size battery bay. (…) It's too early to settle upon a single battery standard, because battery technology is still advancing, producing new potential styles of battery each year" (Thompson, 2009). Despite some of these unknowns, the fact remains that Better Place has attracted over $700 million in financing from multiple outside investors, including HSBC and Morgan Stanley, as well as cooperation from governments in the US, Canada, Australia, Denmark and Israel. Clearly, these are analysts and governments who have concluded that Better Place is proposing an economically and environmentally sustainable transportation solution that addresses and adds value to all involved stakeholders.

Regardless of the uncertain future success of Better Place, however, the case already affords a valuable lesson. Better Place began with a design problem: How can convenient and affordable personal transportation be powered without burning fossil fuels? It turns out to solve the problem, which had previously only been considered from a technological perspective, required a needs-based approach that considered both product innovation and business model innovation simultaneously.

Chapter 6. Interface Case Study

6.1 Introduction

Each business joining the sustainability effort comes from a unique perspective and will often develop its own vision of sustainability. A common approach to becoming more sustainable is to adopt environmental management systems to comply with all applicable laws and regulations and optimize existing processes. Some companies completely redesign their products to minimize the associated environmental impacts of the product over its lifecycle. Furthermore, companies can innovate on a business model level by making major changes to the way they operate, to the customer experience they offer, or to their financial model (Hawken, 1993). This case study looks closely at Interface Inc., a transnational modular carpet tile manufacturer that redesigned its products and its business model to become a more sustainable company.

Interface is the world's largest producer of commercial floor coverings and sells 40 percent of all the carpet tiles used in commercial buildings in the world (Roy, 2009). Interface Global sells flooring products under the InterfaceFLOR, FLOR, and Bentley Prince Street brands which had aggregate worldwide sales of over $1 billion in 2007, with 60% of sales coming from the Americas, 30% from Europe and Africa, and 10% in Asia and the Pacific (Hendrix, 2008). Interface was chosen as a case because in 1994 the company CEO, Ray Anderson, had an epiphany that led to the complete overhaul of the entire organization, which included major changes to both the products it sold and its business model. Similarly to the previous case, this case study begins by describing the company background and events that catalyzed the company wide transformation. Subsequently, this case outlines aspects of Interface's product design, describes the business model innovation that Interface underwent, and then analyses the relationships between product design and the business model in Interface's transition to becoming a more sustainable company.

6.2 Background

In August of 1994, company CEO Ray Anderson had to give a speech outlining his vision for the company's Environmental Policy Task Force. After three weeks of racking his brain over what to present, Anderson finds a copy of *The Ecology of Commerce* sitting on his desk.

> Hawken's message was a spear in my chest that remains to this day. In preparing that kick-off speech, I went beyond mere compliance in a heartbeat. I wasn't halfway through the book before I found the vision I was looking for, together with a powerful sense of urgency. (Altomare, 1999, p. 107)

In his speech, Anderson outlined his vision of Interface's environment policy to the task force. He explained how business has been part of the problem and affirmed that it will be part of the solution. Anderson is an extremely competitive leader and was crystal clear that Interface was going to go all the way with its new higher purpose of becoming a sustainable company. In fact, not only did Anderson give his company a mission to transform into a sustainable company, but a mission to go beyond that and become a restorative company. By his understanding, sustainability means "taking nothing from the earth and doing nothing harmful to the earth. Restorative means giving back to the earth on balance" (Altomare, 1999, p. 111). Furthermore, he explained how Interface will assume a leadership role in industry and be the benchmark against which all companies evaluate themselves. Anderson's vision was revolutionary: Interface was going to lead through example the entire industrial world to a new model of industrial enterprise.

Over the next four months, life as usual changed at Interface. In just the few months before January 1995, Interface's research and development department implemented numerous programs to get the ball rolling. The first was called EcoSense, which was a program to measure the progress that Interface was making as it strives for sustainability. Still in use today, EcoSense is a tool that helps educate employees about what it means to be sustainable, and to uncover ways to make their work more sustainable. Another program established in the fall of 1994, and still very much a part of Interface today, is QUEST. QUEST, an acronym for Quality Utilizing Employee Suggestions and Teamwork, is a result of the "War on Waste" that the company launched to create greater efficiencies in Interface's operations. Essentially, the QUEST program was instigated to identify, measure, and eliminate waste from all Interface operations.

Anderson recounts that the cultural shift was one of the toughest parts of the company-wide transformation. "It took about fifty speeches by me before we really got a lot of buy-in from our people" (Anderson, 2004b, p. 9). Perhaps one of Anderson's most strategic decisions was to form an advisory board comprised of the most respected names in the sustainability movement. Eventually Interface had its own internal "dream team" advisory board of Janine Benyus, Bill Browning, Robert Fox, Paul Hawken, Amory Lovins, L. Hunter Lovins, John Picard, Jonathon Porritt, Daniel Quinn, Dr. Karl Henrik Robert and Walter Stahel. All of these leaders have made great contributions to the sustainability movement, and some have even developed models for what a sustainable society or business would look like. The two models that Interface has used to help guide its operational principles are The Natural Step, developed by Dr. Karl Henrik Robert and Natural Capitalism, a vision founded by Paul Hawken, Amory Lovins, and L. Hunter Lovins. Inspired by the Natural Step and Natural Capitalism models and under the guidance of its advisory board, Interface soon drew up what Anderson calls the Seven Faces of Mount Sustainability. Each face, he describes, represents an area that his company must overcome to become a business that has no net negative effect on the environment.

For Interface, the seven faces of mount sustainability are to eliminate waste, switch to benign emissions, use renewable energy, close the material loop, adopt resource efficient transportation, sensitize stakeholders, and redesign commerce. To eliminate waste, Interface defines waste as any measurable input that goes into their product that does not produce value to their customers, including all raw materials consumed in the production of their carpets. To emit only benign emissions, Interface is hoping to set an industry benchmark by completely eliminating smokestacks, effluent pipes or harmful waste in all of its factories. For the third face, the switch to renewable energy for all of its operations is a top priority at Interface. To close the loop in its manufacturing, Interface has made the commitment to turn all of its products into products that can stay in either biological nutrient cycles, or technical nutrient cycles[4]. Transportation for Interface includes moving people, products, information and resources and Interface acknowledges that the company is dependent on the transportation industry's unsustainable model (Interface Inc., 2007). For the sixth face, all stakeholders including employees, customers, suppliers, communities, and even competitors, needed to

[4] Biological nutrient cycles contain non contaminated organic materials that can be returned to their natural systems and technical nutrients are synthetic materials that can be recycled to become valuable raw materials for industry.

understand that "environmental sustainability is not only the right thing to do, but the smart thing to do" (Interface Inc., 2007)[5].

The last face, redesigning commerce, implies adopting an entirely new way of thinking about business for Interface, and will be elaborated in the following few paragraphs. It entails a shift to a new notion of economics where prices reflect true costs. Interface acknowledges that there are costs associated with bringing their products to market that ultimately get passed on to society and nature. All the emissions and hydrocarbons that negatively affect the environment and society are called externalities because they are costs that are external to the economy and are ultimately placed on shoulders of society in general. Interface is working on "internalizing the externalities associated with hydrocarbons, to create ecologically and socially honest prices" (Anderson, 2004a, p. 36). This front is also about working with external organizations to encourage the adoption of policies that create market incentives for sustainable business. In the current system, numerous "market distortions make it difficult, if not impossible, for markets to recognize the true cost of what they produce" (Interface Inc., 2007). An example of this is the billions of dollars in subsidies that the fossil fuel industry receives that deceptively deflate the advantages of recuperating fossil fuel-based materials for post-consumer and post-industrial recycling.

John Picard, the environmental consultant on an Interface project for the Southern California Gas Company, was unwavering in his stipulation that Interface switch to a service-based business model. This means the company can maintain ownership and ensure proper end-of life treatment, ideally reclaiming the materials to be reintegrated into the material flow of new products. Moreover, this places the incentive for more durable products and the provision of services that increase the durability of the product on the shoulders of the manufacturer. Economically, this model can lead to reduced costs for both the manufacturer by increasing resource efficiency and for the customer by turning a capital expenditure into a monthly tax-free expense.

Interface's answer to the service-based model is the Evergreen Service Agreement (ESA). As described in a Harvard business case about Interface's service agreement, "ESA provided the following: (1) carpet and installation; (2) carpet maintenance; (3) selective replacement of tiles; and (4) carpet removal at the end of its term (reclamation)" (Oliva &

[5] For a more in depth look at the first six faces of sustainability, see Appendix 11: The First Six Faces of Sustainability for Interface.

Quinn, rev. June 4, 2003). ESA more than covered all customers' needs with respect to floor covering and represented a major paradigm shift in the way the company intended to do business. Interface positioned the ESA to capitalize on all of the above advantages for both itself and the customer. The cornerstone of the service was the practice of selective replacement, which capitalized on the fact that generally 20% of a carpet receives 80% of the wear. By only replacing the 20% of the carpet tiles showing wear, Interface achieved a five-fold material savings over the life of the lease (Oliva & Quinn, rev. June 4, 2003). Through selective replacement and numerous other advantages, Interface felt adamantly that ESA could provide a sustainable cost advantage. As will be shown below however, ESA has not proven to be the success it was slated to be.

6.3 Interface's Business Model

Interface uses the seven faces of sustainability to completely transform the way the company creates value for its customers. Essentially, Interface is in the process of transitioning to what it refers to as a new sustainable model for business which is illustrated below in Figure 22.

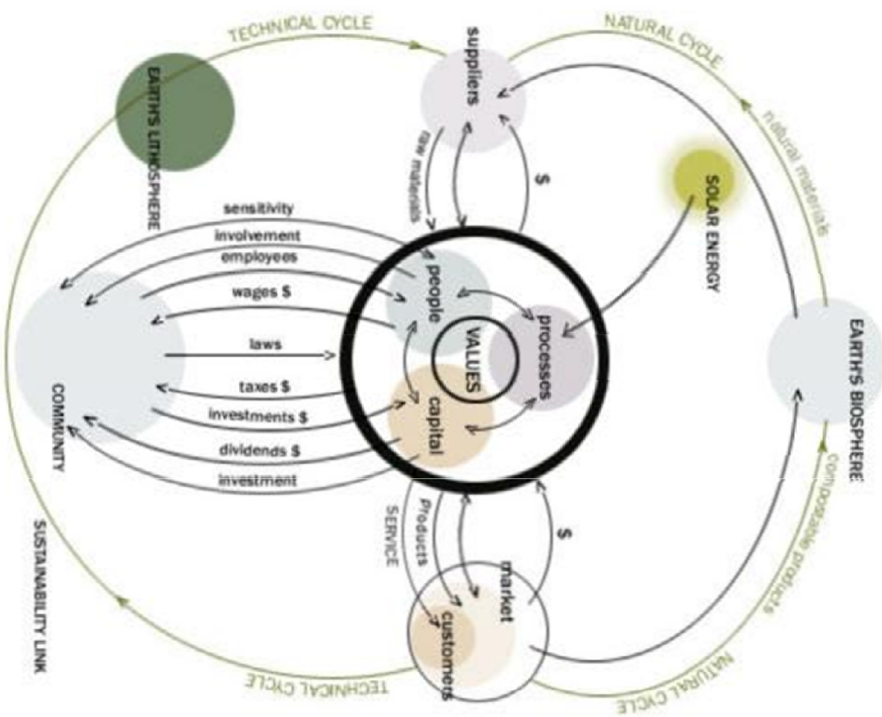

Figure 22: Interface's Sustainable Model of Business (Anderson, 2004a)

Below is the Business model Canvas for Interface (Figure 23) followed by paragraph descriptions of each building block of the business model canvas. Where the seven faces of sustainability manifest themselves on the business model canvas are highlighted in darker grey.

<table>
<tr>
<td rowspan="2">Key Partners

Resource Efficient Transport.

Team of Sustainability Consultants.</td>
<td colspan="2">Key Activities

Design, manufacture and distribute carpet tiles

Constantly improve sustainability – eliminating waste.
Provide ESA Services.
Sensitizing stakeholders.</td>
<td rowspan="2">Value Proposition

High quality commercial floor covering service.

High quality commercial interior carpet tiles.</td>
<td>Customer Relationship

Personal Assistance.</td>
<td rowspan="2">Customer Segments

Large businesses and organizations.

Facility Managers.

Top Executives.</td>
</tr>
<tr>
<td colspan="2">Key Resources

Sustainable Manufacturing Facilities.

(Benign emissions, renewable energy, closed loop manufacturing)</td>
<td>Channels

Direct Sales Force.

Top executives for ESA.</td>
</tr>
<tr>
<td colspan="3">Cost Structure

High Margins on maintenance covering low margins on lease of carpets.
High cost carpet tiles with high margins.
Large volume funds big R+D budget.</td>
<td colspan="3">Revenue Streams

Lease revenue for ESA.

Sales revenue for others.</td>
</tr>
</table>

Figure 23: Business Model Canvas for Better Place

Customer Value Proposition: There are essentially two value propositions that Interface brings to the market. One is the ESA, which is a high quality commercial floor covering service that includes delivery, installation, maintenance, replacement, and removal of carpet tiles. The second offering is simply carpet tiles available for purchase.

Customer Relationship: The customer relationship is very much based on personal assistance. The Interface sales force is highly involved in walking the customer through the decision making and purchasing processes. For the ESA, the company leadership would often be involved in the even more rigorous and engaged process of selling the service agreement.

Channel: The sales channel for Interface products are through their account executives and direct sales force. As mentioned above, for the ESA, the company leadership are often highly involved in the selling process.

Customer Segment: The customer segments that Interface targets cover the whole spectrum of commercial clients, including corporations, higher education, K-12, governments, healthcare, hospitality, libraries, retail, and senior living. Despite the diversity of organizations that Interface caters to, Interface products are premium products that are targeted to organizations that have the ability to make a significant investment in their flooring.

Key Partners: Resource efficient transportation is the front that Anderson admits is the most difficult to address. So much of the transportation related to the procurement of raw materials and the distribution of Interface's products is under the control of the transportation industry. The transportation industry is dependent on fossil fuels to deliver goods and services for its customers and Interface recognizes that this is not a viable model for long-term sustainable transportation. Interface is a partner, however, of the U.S. Environmental Protection Agency's Safeway Transport partnership and has won a Safeway Excellence Award for its efficient logistics developed with its consulting logistics firm Meridian IQ. Interface also seeks partnerships with companies that are addressing the need for a transition to more sustainable transportation. Since innovating transportation falls significantly outside of Interface's core competency, the company sees partnerships in this arena as the only way to ever fully switch to resource efficient transportation. Another key partner for Interface is the company's team of sustainability consultants, who were instrumental in developing a vision of sustainable business and designing a sustainable business model for Interface.

Key Resources: Interface's key resource is the company's network of manufacturing facilities. Without these facilities, Interface would not be able to create carpet tiles and would not exist. The three fronts of sustainability that Interface focuses on that are directly related to its manufacturing facilities are benign emissions, renewable energy, and closed loop manufacturing. The most difficult part of having only benign emissions, according to Anderson, is the work that has to be done upstream to prevent the toxic chemicals from coming into the factories in the first place (Anderson, 2004a). The toxic chemical elimination project is an initiative designed to fight this front. Its first actions included the elimination of all chemicals whose usage needed to be disclosed to the Environmental Protection Agency (EPA). Other areas that this front is addressing are water management and indoor air quality. Currently, seven Interface facilities operate with 100% renewable electricity that comes from a variety of sources including solar power, wind power, and biomass. Wind power is already competitively priced with fossil fuels, but Interface does pay a premium on some sources such as solar. Anderson justifies this decision by saying that Interface's improved efficiencies afford it the ability to pay the premium to do the right thing (Anderson, 2004a). In terms of closing the loop, the ability to recycle Nylon 6,6 combined with their new "Cool Blue" technology that recycles vinyl backing from reclaimed carpets means that Interface is closer to the point where no carpet ever needs to go to a landfill or incinerator (Revis, 2008).

Key Activities: There are numerous key activities in Interface's business model. Primarily the company designs, manufactures, and distributes carpet tiles. In addition to these activities, under the ESA, the company installs, maintains, replaces, and reclaims carpet tiles. These key activities are closely related to closing the loop at Interface. The ability to close the loop at Interface rests heavily on the shoulders of the product designers. They must find ways to develop products that use materials that can be re-integrated into their production process. What makes Interface stand out from other companies trying to close the loop is that Interface is actually trying to use old carpets to produce new carpets. Many companies design products that can be recycled, but the physical properties of the recycled material are insufficient to be reused in the original industrial process.

Two other key activities in Interface's sustainable business model are eliminating waste and sensitizing stakeholders. Eliminating waste is essentially the first area of concentration for Interface in its transition toward sustainability. The QUEST program described above is the primary method used within the company to identify and eliminate any products or processes that may be wasteful. The QUEST initiative is part of the company's total quality management program where quality means zero waste. The goal of achieving zero waste is placed firmly for the year 2020. As of 2006, the company has cumulative avoided cost from waste reduction totalling almost 350 million dollars (Interface Inc., 2007).

Sensitizing stakeholders means creating a community that is interested in environmental issues, so prospective employees may already be sensitized to the ideals that Interface promotes; it means suppliers can reap the same benefits and help reduce the impacts of Interface's supply chain; and it means increasing demand for sustainable products, which can lead to sales growth and increased market share. This front is about making sure that everybody is on the same page, and is the reason for all of the public speaking engagements that Anderson and other Interface employees have participated in. Interface now views itself as a self-sustaining ecosystem where cooperation replaces confrontation.

Cost Structure: Interface sells high quality products that are costly to produce. Furthermore, Interface has invested in extensive research and development to become a more sustainable company. The result is a high cost product with premium recycled materials and manufacturing processes. High margins on their premium products are what fund the expenses of renewable energy, and constant research and development on becoming more sustainable. The ESA provides premium carpet tiles combined with premium services. The high margins on the services subsidize the cost of the carpet tiles so Interface can lower the lease price.

Revenue Streams: Interface gets one time revenues from sales of carpet tiles. For the ESA, Interface gets revenues for installation, maintenance, replacement, and recuperation of carpet tiles. A single monthly fee covers all expenses and is evenly distributed over the entire length of the lease agreement.

6.4 Product Design at Interface

We have seen how Interface has overhauled its business model to shift to a sustainable model for business and engaged all levels of the organization to contribute to seven faces of what the company refers to as mount sustainability. However, the design department has a particularly special role to play. As Anderson describes it, "To make real progress, the product development people need to understand what sustainable design is, and should be wholeheartedly involved in moving in that direction" (Anderson & McDonough, 1998, p. 11). To help product designers keep materials in a closed loop, the design teams use what are called the Steps to Sustainable Products (Figure 24).

The first step is to start doing something, keeping in mind the principles of minimizing material use, and attempting to use recycled and recyclable materials when possible. Minimizing material can lead to great cost saving and environmental benefits, yet recycling and using recycled materials have less concrete benefits. Despite in some cases using 60% less energy, recycled materials can be significantly more expensive than virgin plastic, which can be a major inhibitor to closing the loop (Terracycle, 2008). The ability to recycle nylon 6,6 has brought Interface one step closer to closing the material loop, but actually developing a highly profitable product with recycled materials poses further difficulty. These are the types of problems that Interface product designers are looking to solve.

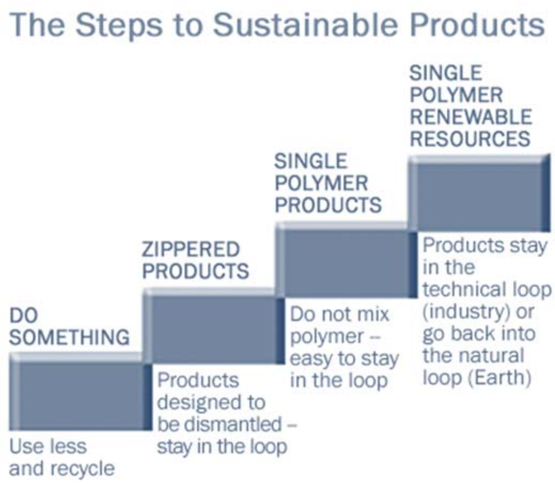

Figure 24: The Steps to Sustainable Products (Interface Inc., 2007)

The second step is to assure that products can be separated from their environments and the individual components can be separated to stay in the loop. The third step is to design components without the need for a mixture of polymers so that the materials can be valuable when recycled. David Hobbs, president of InterfaceFLOR Commercial acknowledges that, "One technological hurdle the industry has faced is the ability to separate carpet face fiber from backing in a way that preserves the materials in a pure enough form for recycling, and in a way that is economically feasible" (Revis, 2008). Although some products contain numerous materials that need to be separated, the ultimate goal is to assure that all polymers are pure and can be recycled without being diluted with other polymers in the mixture. Lastly, the product should only contain technical or biological nutrients, each of which can stay indefinitely in the closed loop. This has been an area that has been difficult for Interface designers. This step states that if the materials cannot be used infinitely in a closed loop, then they must be substituted with a material that can be. Interface has been keeping the materials that best meet the needs of the product from a quality perspective, namely Nylon 6,6 and PVC backing, and has been extremely patient and determined with research that has led to breakthroughs in the ability to keep these materials in closed material loops.

The following paragraphs outline the details of product design at Interface, by looking at the five primary aspects of the carpet tiles that Interface sells. These five aspects are carpet tile form factor, carpet face material, carpet backing material, carpet aesthetics, and adhesives.

Carpet Tile Form Factor: Carpet tiles are different from traditional wall-to-wall carpeting in the respect that carpet tiles are modular square sections, about 18 inches by 18 inches that cover a floor with many individual tiles, as opposed to one large sheet of broadloom carpet. Carpet tiles were introduced to the North American market in the 1970s when Anderson started Interface, and they disrupted the commercial flooring market through their many advantages over broadloom carpet. The decision by Ray Anderson to make carpet tiles when he was founding the company was already a design decision that led to minimized waste and reduced costs, compared to producing carpet in the more traditional wall-to-wall format. To maximize the benefits of this floor covering design, Interface at one point held seminars to train carpet installers on how to install the tiles while minimizing waste.

Carpet Face Material: Carpet material is a key factor in the quality of carpet tiles. However, developing materials and processes that can meet the "closing the loop" criteria is difficult. Compared to the infinitely recyclable nylon 6, nylon 6,6 is the stronger, more durable material that makes far better carpets. In 2006, a new technology was developed in Italy by Sergio Dell'Orco and Frank J. Levy, co-owners of Post-Consumer Carpet Processing Technologies LLC (PCC) that enables the recycling of nylon 6,6. This has been a huge breakthrough for Interface in terms of closing their material loop. Today, Interface uses this technology in their Convert line. Convert is a recycled nylon face fiber, made from turning nylon 6 and 6,6 into a clean stream of post-consumer nylon.

Carpet Backing Material: QUEST defined waste as, "every measurable input that did not create customer value, with all raw materials consumed in the production of carpet materials considered waste" (Oliva & Quinn, rev. June 4, 2003, p. 4). Clearly this puts a great portion of the waste elimination effort on the shoulders of the designer. The product designers need to design carpets that not only eliminate by-products in the production process or, waste scraps in the installation phase, but also minimize the amount of material present in the final product. Interface designers have addressed these issues through such innovations as reducing the average tile backing weight by 15% which saves both materials and energy (Rouse, 2006). One of the most recent carpet tile designs, called Contact Release™, contains as many as 6 unique layers that can be separated (Figure 25). The product is a patented backing technology that allows the tiles to bond with virtually any smooth surface, without the need for adhesives.

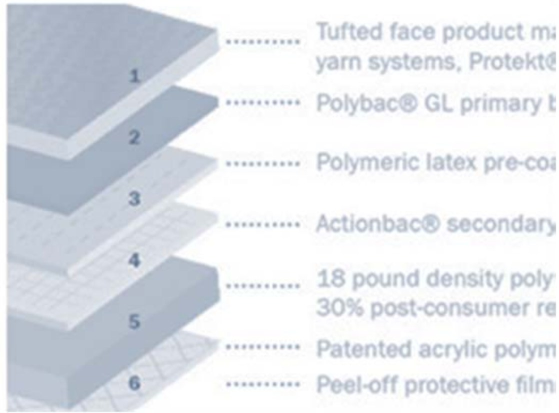

Figure 25: Contact Release™ Layers (Interface Inc., 2009c)

Carpet Aesthetics: As Anderson explained in an interview with *Engineering Enterprise*, the head of product development sent his entire design team into the forest, with the mandate of looking to see how nature would design a floor covering. They realized that no two areas of the forest floor or streambed were the same, and if a stick was moved from one place to another, no one would notice. The total effect was a sort of organized chaos and diversity. Applying these principles to carpet design, the design team came up with Entropy, a carpet tile where no two tiles were alike but when placed together, they created a uniform and pleasing aesthetic (see Figure 26).

Figure 26: Non-Directional Carpet Tiles (Interface Inc., 2009d)

In fact, because of this non-uniform design, any defects in the tiles are completely camouflaged eliminating all of the waste associated with manufacturing defects. Furthermore, the installation process has almost no waste. When the installation team gets to the wall edge and has to cut the carpet tile, the remaining piece can be used elsewhere in the installation (Anderson, 2004b). This strategy leads to less material waste – 1.5% with the entropy installation compared to 3-4% with typical carpet tile, and as much as 13-20% or more with other carpet products (Interface Inc., 2009c). Today, Entropy is just one of many designs that fall under the Label of i2, the non-directional carpet tile category.

Adhesives: The second face of sustainability for Interface is benign emissions. One of the major factors in creating benign emissions is eliminating toxic chemicals from the production processes. Interface needs to design carpet tiles that do not require toxic chemicals to keep them clean. They also need to design carpets that can be produced by clean production methods and do not need to be incinerated in their end-of-life treatment.

The Interface design team has actually played a significant role in eliminating toxic chemicals needed in the life cycle of the carpet tile. In 2003, the carpet tiles where essentially made from three layers: 20% of the total material was a very durable top layer composed of Nylon 6,6, the bottom layer which accounted for about 60% of the material was recyclable PVC, and the middle layer and remaining 20% of the material was an adhesive holding those two layers together (Oliva & Quinn, rev. June 4, 2003). An additional layer however, was also needed. The carpet tiles were kept in place with adhesive glue that fixed each carpet tile in place, a process that complicated installation and made tile recuperation almost impossible. The Interface design team found a way to eliminate these toxic chemicals by developing an installation system call TacTiles® which consists of an upside down sticker that hold 4 tiles together at each intersection (Figure 27). The tiles are thus interlocked and "float" on the floor but are held static by the fact that the walls enclose the carpet tiles. The TacTiles® innovation resulted in an ecological footprint 90% lower than that of the original glue adhesives. The contact release product described above also is an innovation that eliminates the need for chemical adhesives.

Figure 27: Tac Tiles (Interface Inc., 2011)

6.5 The Product Design and Business Model Relationships at Interface

The following 6 tables systematically identify the relationships that exist between product innovation and the business model at Interface. Each table represents a particular aspect of product design and the building blocks of the business model that the aspect has a noteworthy relationship with. These same methodology used in the previous case has been applied.

	Carpet Tile Form Factor
CVP	The carpet tile form factor is **essential** to being able to provide a service-based customer value proposition (DSBM).
Revenue Structure	The carpet tile form factor is **essential** for a service-based revenue model (DSBM).
Key Activities	The carpet tile form factor enables the switching out of damaged areas of the carpet and is **essential** to making the concept of providing a floor covering service possible (DSBM). The carpet tile form factor significantly contributes to reducing waste by enabling selective replacement (DSBM).
Customer Segment	The carpet tile form factor, which was the driving force for starting Interface, is primarily suited for businesses and institutions and is a **key driver** of the targeted customer segments (DABM).
Cost Structure	All of the material efficiencies and time savings that carpet tiles afford **help** to keep margins high and subsidize high research and development costs (DSBM).

Table VIII: Carpet Tile Form Factor / Business Model Relationships

	Carpet Face Material
Key Resources	Having factories with Cool Blue technology that emit benign emissions and can close the loop on the Nylon 6 and 6,6 are **essential** to being able to use them in carpet face material (BMSD).
CVP	The carpet face material is **vital** to a value proposition of high quality products and services (DSBM). The better the quality of the face material, the more it supports the business model.
Key Activities	Using materials that exist in closed loop material flows is **central** to eliminating waste, a key activity for Interface's business model (DSBM).
Revenue Structure	Carpet face material that can be recycled must be recuperated which is a revenue generating service and thus **contributes** to revenue streams (DSBM).
Cost Structure	Carpet face material that is durable and easy to maintain **helps** increase margins of the ESA (DSBM).

Table IX: Carpet Face Material / Business Model Relationships

	Carpet Backing Material
Key Resources	Having factories with Cool Blue technology that emit benign emissions and can close the loop on the Nylon 6 and 6,6 are **essential** to being able to use them in carpet backing material (BMSD).
CVP	The carpet backing material is **vital** to a value proposition of high quality products and services (DSBM). The better the quality of the backing, the more it supports the business model.
Key activities	Using backing materials that can be separated and add to closed loop material flows is **central** to eliminating waste, a key activity for Interface's business model (DSBM).
Revenue Structure	Carpet backing material that can be recycled must be recuperated, which is a revenue generating service and thus **contributes** to revenue streams (DSBM).
Cost Structure	Carpet face material such as Contact Release™ reduces the need for adhesives and **helps** to increase margins in the ESA (DSBM).

Table X: Carpet Backing Material / Business Model Relationships

	Carpet Aesthetics
CVP	Carpet aesthetics are **central** to offering a high quality carpet tile to Interface's customers (DSBM).
Key activities	Non-directional carpet designs reduce material waste in the installation phase, which **significantly contributes** to the key activity of reducing waste (DSBM). The key activity of providing the ESA services is an **important driver** for the installation time and cost efficiencies afforded by non-directional carpet design since installation and replacement services are internalized (BMSD).
Customer Segment	The customer segment is a **key driver** of all carpet designs which provide the customer segments with flooring options that meets their aesthetic as well as functional needs (BMAD).
Cost Structure	Non-directional carpet designs that minimize waste and installation time in the installation phase **help** increase margins (DSBM).

Table XI: Carpet Aesthetics / Business Model Relationships

	Adhesives
Key Resources	Using non-toxic adhesive strategies such as Contact Release™ or TacTiles® is **essential** to having manufacturing facilities that produce benign emissions (DSBM).
Key Activities	The key activity of providing the ESA services is a **key driver** in innovating product aspects such as the adhesives because the time and cost efficiencies associated with installation and replacement are internalized (BMSD).
CVP	Non-toxic adhesives **significantly add** value to carpet tiles, as customers perceive ecological products as premium quality (DSBM).
Customer Segment	Installation time is a **key** selling point for commercial flooring customers and adhesives such as TacTiles® drastically reduce carpet tile installation or replacement time (DSBM).
Key Activities	The facility of carpet tile installation and replacement afforded by TacTiles® **greatly facilitates** the key activity of providing the ESA services (DSBM).
Cost Structure	Reduced cost and increased speed of installation and replacement afforded by these adhesive innovations **significantly increases** margins for the ESA (DSBM).

Table XII: Adhesives / Business Model Relationships

6.6 Results and Interpretation

Of the 45 possible relationships that could come from looking at how each of the 5 main aspects of Interface's product designs relates to each of the 9 building blocks of the Interface business model, 24 relationships were identified. Of those 24 relationships, 8 are identified as vital relationships, 11 are identified as significant relationships, and 5 are identified incidental relationships.

Furthermore, within those 24 relationships, there are 21 instances where design supports the business model (DSBM); 3 instances where the business model supports design (BMSD); 1 instance where design affects the business model (DABM); and 1 instance where the business model affects design (BMAD). Table XIII summarizes where the relationships exist and denotes the level of significance of each relationship.

		Aspects of Product Design				
		Form Factor	Carpet Material	Backing Material	Carpet Aesthetics	Adhesives
Business Model Building Blocks	CVP					
	Customer Relationship					
	Channel					
	Customer Segment					
	Key Partners					
	Key Resources					
	Key Activities					
	Cost Structure					
	Revenue Streams					

Table XIII: Significance Level of Product Design and Business Model Relationships at Interface

There are a few noteworthy aspects to the relationships that have been identified. Clearly, in this case, sustainability at Interface has been fully integrated into the business model, and is a key element in the way it creates value. As such, all ways that the product designs lead to sustainability are instances where design supports the business model. The development of Cool Blue technology, which is a key resource related to Interface's manufacturing facilities that recycles carpet materials into new carpets, is perhaps the most significant way that the business model supports product design. The company is committed to closing the loop on its material flows, yet is also committed to designing products that meet the highest standard for quality and durability, which means using Nylon 6 and Nylon 6,6.

Interface's recycling technology allows them to meet their quality standards while simultaneously staying true to their commitment to closed material flows.

A second noteworthy aspect is that three business model building blocks are unrelated to product design: customer relationship, channel, and key partners. They are certainly related to other aspects of the business model, but this research intends solely to focus on the relationships between product design and business model building blocks. The customer relationship building block is mainly about personal assistance, and this is truly a function of the nature of the flooring industry. There are so many styles and options, that direct personal assistance is necessary for the customer. As far as the channel, the direct sales force is quite independent of the product design; however, as the product, and especially the ESA, get more complicated, the tasks of the sales force are equally complicated. Lastly, key partners in this case seem quite unrelated to design decisions. A key partner for Interface is a sustainable transportation service, and while minimizing material use would result in less environmental impacts associated with the transportation stage, the efficiency of the transportation itself is a matter that lies in the hands of those in the transportation industry.

Lastly, despite the ability to offer a new revenue model without any product innovation, product innovation can play an integral role in making the new revenue model more profitable and sustainable. One of the most informative aspects of this case is the attempt by Interface to switch to a service-based value proposition, and the associated switch to a lease payments revenue model. Interface decided to bundle the installation, maintenance, and removal services with the product, and offer the client the option to pay a monthly floor covering fee, as opposed to a one time purchasing price. The major shift that took place was not on the product level, but was with respect to the revenue model associated to the product.

When looking at each stage of the ESA, it is possible to see how the product can be optimized for that process. One of the major shifts for Interface that came along with the ESA, was the formation of Re:Source, a separate business unit responsible for all carpet related services such as installation and maintenance. These contractors would directly benefit from carpet tiles that are designed to be installed more quickly and easily. In addition to minimizing the waste associated with installation as stated above, non-directional carpet tiles are far faster to install. All the time needed for tile selection and pattern arrangement is eliminated, which highly reduces the costs connected to this labour intensive service (Interface Inc., 2009c). The installation costs are further reduced by the use of Interface's TacTiles™, as the means of fixing the tiles in place. The cost savings from TacTiles™ are due to the speed with which the tiles can be locked in place, the correction of errors if need be, and the elimination of the need for adhesives. Providing the installation service under the ESA business model would help Interface benefit directly from these cost reductions.

Interface has developed product innovations that greatly help in minimizing maintenance costs and increasing the longevity of its carpet tiles. A good example is Protekt2®, an advanced soil and stain protection that is applied to each fiber during the manufacturing process, without yellowing or dulling the carpet surface (Interface Inc., 2009b). Again, the ESA would allow Interface to financially benefit from the reduced maintenance costs and longer expected carpet tile life. Through ESA, Interface is responsible for tile replacement and all of the associated costs. By innovating on the business model level, Interface is able to benefit from the innovations on the product level that reduce the costs of providing the associated services.

The goal of reclamation and re-entry is to close the material loop. Closing the material loop is one of the primary reasons that John Picard had originally suggested to Joyce Lavalle and Ray Anderson that Interface explore servicizing its business model to maintain ownership of its products. By trying to maintain ownership, Anderson could ensure that all carpet tiles were treated appropriately at their end-of-life. Of course, ensuring carpet tiles stay in closed material loops is easier said than done. Firstly, reclaiming carpet tiles incurs considerable costs. Secondly, it must be technically possible to separate all of the materials. Finally, the materials must actually be recyclable. Ideally the recycled materials re-enter the very same material flows from which they came, so that end-of-life carpet tiles are reincarnated into newly woven carpet tiles. These barriers to closing the material loop are major design challenges for Interface's product designers. All the ways that product innovation can help close the material loop are already mentioned above.

Ultimately, maintaining product ownership is not imperative to closing the material loop, but is one way to ensure that it happens. Even if carpet tiles are purchased outright by customers, as is the case with the vast majority of Interface sales, carpet tiles can still be reclaimed from sources that are willing to pay to have their carpet tiles reclaimed. Product innovations that reduce the costs associated with the reclamation process and that make closing the material loop possible were helpful in trying to make the ESA a commercial success. The ESA, however, still hasn't been successful. In fact, in 2005, Interface sold all of its service providing Re:Source dealer businesses due to a downturn in the market and intense pricing pressure (Hendrix, 2008). The product design innovations described in this section can lower the cost of many of the services associated with carpet tile use. Even if Interface is no longer providing these services themselves, the product innovations remain huge selling points for potential buyers. These innovations help lower the costs and thus increase the value of the carpet tiles over their entire lifecycle.

The story of Interface's transition has become a legend in the business community. By the end of 2007, Interface had avoided over $372 million in cost through waste elimination activities, had diverted over 133 million pounds of material from landfill; had managed to source over 25% of all energy used in carpet manufacturing facilities from renewable sources; and over 25% of all raw materials used in carpet manufacturing were recycled or bio-based materials (Interface Inc., 2009a). Nevertheless, in 2003, only 6 ESA agreements had been signed.

So what happened? There are many theories that try to explain the failure of the ESA to catch on as a meaningful part of Interface's sales portfolio. Even internally, there seems to be disagreement among executives as to why it is not taking hold. The Harvard Business case by Oliva & Quinn lists some of the barriers. One company officer described it as too complicated for customers to understand - even if at first the ESA intrigues potential clients, once they are presented with the details, they are overwhelmed and stick to what they understand. Others believed that the day-to-day sales force needed to be more included in the sales pitch, as opposed to the current strategy of flying in the top company officers to make the deal. Lastly, others believe that once they get more agreements signed, they will have incentives to make further innovations, such as reducing maintenance costs and increasing recyclability. Yet without those innovations, it is hard to increase ESA sales (Oliva & Quinn, rev. June 4, 2003).

There is one element, however, that all executives close to the program agreed was a major barrier to ESA sales: sticker shock. Interface packaged the ESA as a single service that included all floor covering needs. The mandatory maintenance services that the ESA included were extremely high end services meant to yield high profit margins for Interface, and to ensure a long healthy life for the carpet tiles. Many companies were being asked to pay for services they weren't interested in, and that didn't give them any value. Anderson has his own explanation for why the ESA is still grounded. It goes back to his concept of redefining commerce. According to Anderson, redesigning commerce is not just about switching to a service-based model that creates market-based incentives. It also "involves the acceptance of entirely new notions of economics, especially prices that reflect full costs" (Anderson, 2004a). In a candid interview with *Engineering Enterprise*, Anderson was asked, "You also had some ideas about leasing carpet?" Anderson's response was, "That's gone nowhere." He explains:

> You still have oil subsidized to a terrific degree, so anything made from oil is basically subsidized. You have an artificially low market price for the virgin materials; consequently, you don't have the value in the recycled material that you would have if prices were honest. Instead, we have this basically blind and dishonest marketplace. (Anderson, 2004b, p. 10)

Because the fossil fuels industry is so heavily subsidized, the cost of petroleum is undervalued. This in turn leads to an elimination of any salvage value for carpets at the end of lease, because it is more cost effective to just extract more raw materials. Essentially, these subsidies benefit companies who are not making any attempt to close the loop on their material flows, and hurt the companies that are. Furthermore, according to tax laws for lease agreements, products with no salvage value after the end of the leasing term have technically been purchased, so the lease agreement is deemed a capital lease and not an operating lease. Because of these laws, the customer cannot include the lease payments in their operating expenses, which would mean the lease payments would be tax deductible.

6.7 Interface Case Conclusion

The Interface case provided some valuable insight on the relationship between product design and business models. Summarizing the results of the Interface case, the defining elements of this relationship are the carpet tile form factor, the service-based revenue model, the sustainable closed-loop manufacturing, and the key activity of constantly improving the company's sustainability. Many of these elements interact in ways where design supports the business model. For example, the carpet tile form factor is essential in providing the service-based CVP and the service-based revenue model; material choices and design for material separation is key to enabling closed loop manufacturing; non-directional carpet patterns support the key activity of reducing waste; and innovative adhesives support sustainable manufacturing and efficient provision of carpet maintenance services. The business model also supports design at Interface in that innovative recycling resources can recycle the kinds of high quality materials that designers want to use, and the service-based business model helps to internalize many of the benefits of product innovations.

From a sustainable business model perspective, the insights from the Interface case stem mainly from the role that a switch to a service-based revenue model was supposed to play. Ultimately, Interface has become an industry leader in sustainability - not through a switch to a service-based revenue model as expected, but through integrating a detailed sustainability initiative into the company's business model. It has been shown how a service-based revenue model would keep all of the financial incentives in the hands of Interface, but environmentally speaking, in the carpet tile industry, the service-based revenue model does not bring any environmental benefits that cannot be achieved otherwise. Waste can still be eliminated, emissions can still be benign, renewable energy can still be used, material loops can still be closed, resource efficient transportation can still be implemented, and stakeholders can still be sensitized.

The service-based business model has proven to be very successful in other industries with the success of ZIPcar in offering car sharing services and Xerox in leasing and re-manufacturing printers. Interface, however, due to petrol industry subsidies, tax laws, low carpet tile salvage value, and other reasons, is not currently in a position to benefit from such a model. The point remains that for Interface, as is the case with numerous other businesses, the goal is to achieve zero negative impact on the environment. A service-based model may or may not be the best way to get there, but a business model that focuses on this goal, and product innovation that supports this focus, can have great benefits.

Chapter 7. The Metacycle Case

7.1 Introduction

The highly resource inefficient nature of our "throw-away" culture has motivated a quest to finding ways to reuse objects and materials that would otherwise be disposed of. A research project by the name of Metacycle proposes an alternative to the environmental impacts associated with new raw material extraction, processing, manufacturing, and even recycling, by giving second lives to the objects that are already in our material streams. The Metacycle website, www.metacycle.ca, was envisioned as a possible one-stop shop for offering creative "reuse" ideas for everyday objects (Lalande, Racine, Colby, & Joyce, 2008).

The most common form of reuse today, called remanufacturing, has already developed into a multi-billion dollar industry led by such multi-national corporations as Xerox and Caterpillar. Re-manufacturing is a process of recapturing the value added to the material when a product was first manufactured, by bringing a used product or component to the same performance standards as in their first use, much like refurbishing (Gray & Charter, 2008). Metacycle builds on this concept by attempting to find ways to repurpose obsolete objects in contexts outside of those for which they were originally designed. Metacycle is a collaborative project between the Université de Montréal and Concordia University that was funded by the Hexagram Institute. The goal was to explore the potential of using direct digital manufacturing (DDM) technology to give a second life to end-of-life products. As a pilot project, Metacycle set out to develop an online community of designers and consumers, and to run design competitions for ideas on how to reuse objects that would otherwise be disposed of. The ideas were judged, and the winning idea was developed into a product that could be manufactured with DDM technology on demand, and sold online through the Metacycle website (Figure 28).

Figure 28: Winning Design Concept (left) and Final Product After Metacycle Design Development (right)

7.2 Background

The Metacycle Website: The Metacycle website is the user facing side of the Metacycle project. The website is intended to be a place where a community of creative, ecologically minded people can communicate, post reuse design ideas, browse reuse projects they can do at home, and buy products that can be combined with end-of-life objects. The primary sections of the Metacycle website are the Design Lab, the profile pages, and the forum. The Design Lab is a database of community generated ideas that teach people how to transform objects and materials that they have readily available, into functional and beautiful products (see Appendix 12: Screen Shot of Metacycle Design Lab). The phenomenon of home building projects has become known in creative circles as do-it-yourself (DIY) projects, a phenomenon that is growing in popularity. All designs, and the accompanying instructions on how to carry out the project, are uploaded to the website by the public through the custom designed interface of the Design Lab. The concept of user generated ideas is another growing trend called crowdsourcing (Joyce, 2009; Lalande, Racine, Colby, & Joyce, 2008). Another feature of the website is a social network that unites all stakeholders involved in material reuse through profile pages. All members can communicate through both public and private messages on each other's profile page. The Metacycle forum allows people to post information about exchanging material or objects, and serves as a venue for asking questions, posting answers, and discussing relevant issues.

Direct Digital Manufacturing: The Metacycle team offers another level of support in finding second lives for objects: Direct Digital Manufacturing (DDM). DDM is a fabrication process that takes a computer aided design (CAD) model of an object and uses additive fabrication technology to build up the shape of a part, one layer at a time, with no wasted material. Traditionally, additive fabrication technology is used for prototyping product concepts to work out design details before investing in expensive production moulds. Known as rapid prototyping, this form of additive fabrication is an intermediary step for pieces that will eventually be manufactured through such processes as injection moulding. DDM refers to the use of this technology, not to produce prototypes, but actual end use products. This technology enables Metacycle to essentially print complex plastic parts on demand, with no upfront costs for tooling or any other fixed costs. This means that community members can design original parts to be combined with end-of-life objects to create an innovative hybrid product composed of reused objects and new parts. For example, in Figure 28, the white disk in the center of the clock is produced through DDM to be combined with markers that have run out of ink. Metacycle.ca sells and fabricates these parts for customers on demand. DDM technology is available at facilities around the world, so Metacycle can use DDM in house for local customers, or outsource jobs to be fabricated in close proximity to the end user.

The implications of DDM go beyond design and manufacturing, and can impact the processes and business model of an organization (Crump, 2008). Metacycle.ca seeks to define an alternative model of production and consumption based on repurposing and DDM. Generally, objects that are repurposed are not combined with new parts in order to fulfill their modified function. However, the ability of building new parts through DDM opens up a world of additional possibilities for repurposing. In this case, the result is a hybrid product composed of a modified obsolete object and a custom designed part built with the DDM technology. As it turns out, the benefits and limitations of DDM (Table XIV) are extremely well suited to the context of repurposing products.

Benefits	Limitations
• Zero tooling • Fast time-to-market • Complex part manufacturing • Mitigates sales forecasting • Can continuously optimise part	• Expensive • Slow • Limited part accuracy • Limited surface characteristics • Limited material options • Limitations of physical properties

Table XIV: The Benefits and Limitation of DDM Compared to Injection Moulding (Crump, 2008b)

To begin with, DDM is appropriate for low production volumes, and because of the unpredictable availability of some obsolete products, low production volumes can be expected. In addition, repurposing is a relatively new concept, so it may be more difficult to predict long-term sales forecasts than when bringing a more traditional product to market. DDM allows one to build on demand with no upfront costs, eliminating this risk. Updates in product design and customization, which can be necessary for repurposing, are handled easily with DDM technology. Consequently, this considerably reduces the time-to-market. Within the context of repurposing, the constraint of the original object must be considered. DDM's ability to create complex parts addresses this issue.

Should a second life concept require the production of one or more manufactured parts, DDM offers the flexibility to produce such parts on demand, anywhere in the world where DDM services are available. Because of DDM's custom capability, Metacycle sees the potential of a network of international DDM facilities so that ideas presented on the Metacycle website may be produced as close to the customer as possible (Rhoades, 2009). This distributed DDM production model may be a pertinent way to reduce the environmental and economic costs associated with such a low volume and customized production. It is important to emphasize that with this business model it is not the product that is shipped internationally, but the data file, representing an entirely new model of production.

Environmental Evaluation of Metacycle: The combination of using end-of-life objects as a source of raw materials, and using DDM as the production method for some components, differs greatly from a traditional product development strategy. To assess the environmental benefits and limitations of this approach, a comparative Life Cycle Analysis (LCA) of the clock developed by Metacycle, and a clock already available on the market, was conducted. The clock developed by Metacycle combines end-of-life markers with a clock casing produced through DDM, and the "Sunburst" wall clock was purchased and used as the comparative product. The results of the comparative LCA were presented by Charles Colby and Carmela Cucuzzella at the conference, Sustainable Innovation 2009, at the Center for Sustainable Design in Farnham, England. As it turned out, the Metacycle clock had less environmental impacts compared to the Sunburst wall clock (Colby, Cucuzzella, & Lalande, 2009).

The Metacycle clock tries to exploit the benefits of a distributed production model with reusing materials. The standard wall clock, however, tries to exploit the low cost of centralized production in the Far East. Ultimately, the Metacycle model proposes a shift from a system with high impacts in the transportation phase (standard wall clock) to a system that has high impacts in the production phase (Metacycle clock) (See Appendix 16: Comparative LCA of Two Clocks in the Metacycle Model). There are two advantages to this switch. First, there is a shift from a process that burns fossil fuels (transportation) to process that uses electricity (DDM). Currently there are more options to source renewable energy for a manufacturing process than for long distance transportation (e.g. purchasing renewable power from a local utility or generating solar power on site). Second, this shift away from a transportation focused model also reduces the packaging impacts. Products are often packaged individually for sales, but require additional packaging when shipped in large quantities. Another reason why packaging impacts are reduced in the DDM clock is because much of the DDM clock material will come from the customer's home, where they will repurpose an obsolete object (Colby et al., 2009).

7.3 Product Design at Metacycle

Product design at Metacycle has been classified into four primary characteristics that are looked at in terms of their relationship with elements of the Metacycle business model: reused materials, DDM material, form and aesthetics.

Reused Materials: One of the cornerstones of the Metacycle concept is the reuse of objects that would otherwise be disposed of. This has numerous environmental benefits such as preventing or delaying these objects from entering landfills, reducing raw material exaction, and eliminating the need for processing, manufacturing, transportation, and even energy intensive recycling. Some projects on Metacycle are just transformations of old objects, while others combine new DDM parts with reused objects such as the Metacycle wall clock.

DDM Material: Material selection for the DDM process is much more limited than parts fabricated through such processes as injection molding, which offer hundreds of different plastic and metal alloy options. Options are increasing, however, and some prototyping companies are now offering as many as 20 different material options, including plastics (e.g. ABS, polycarbonate), metals (e.g. stainless steel and silver), and recycled soda-lime glass. The environmental benefits and limitations of using these materials, however, have not yet been analysed. The material that was used for the Metacycle wall clock and evaluated for its environmental impacts is acrylonitrile butadiene styrene (ABS).

Form: One of the key benefits to DDM is that part geometries are not subject to the limitations of being made in a mould, and thus can be extremely complex and shaped in ways never seen in traditional products. The designs of the DDM parts for Metacycle, however, require some very particular features. There are numerous considerations necessary at the design stage for both DDM's economic and environmental viability. First of all, given the high costs of DDM, material efficiency is paramount. Products must be designed from the beginning to be as small and as material-efficient as possible. Fabrication time is also a consideration. Given the nature of DDM, some part geometries can be produced more quickly than others, and since machine time is a direct factor in the cost of fabricating a piece, the form must take this into consideration. Furthermore, DDM parts do not have the same properties as injection moulded parts, and designs must take into consideration such factors as how the additive layer construction affects material strength. Lastly, designers can optimize part geometries to avoid the use of support material. Support material is a removable material needed to support certain part geometries. The use of support material adds machine time, costs, and unnecessary ecological impacts. Design optimization of the Metacycle clock casing, by using teardrop shaped holes of the marker, led to the elimination of the need for support material (Figure 29).

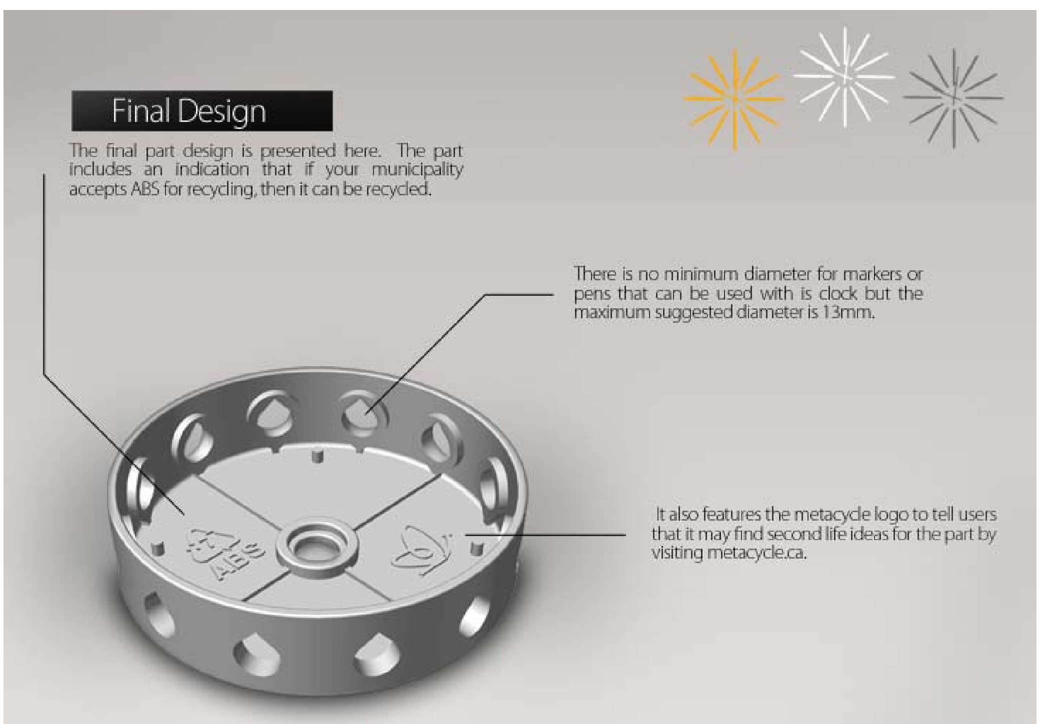

Figure 29: Metacycle Clock Casing - Note Teardrop Hole Shape that Requires No Support Material

Aesthetic: Because DDM parts are fabricated on demand and shipped to customers directly from the closest prototyping company, the surface of the parts are not finished in any way. The way they come out of the DDM machine is how the customer will receive them, and DDM has a much rougher surface than injection moulded parts. There are limited options for finishes such as glossy, soft-touch and matt. To offset this limitation, designers can design textures right into the DDM part to enhance uniformity of the surface and add aesthetic interest. Another aspect of the aesthetic consideration for Metacycle projects is that since objects are being reused, particular attention is often placed on finding ways to integrate the reused materials in ways that either disguise their previous life to make the product look entirely new, or to use the reused material in a way that creatively celebrates the material's previous life.

7.4 Metacycle Business Model

Developing a business model for Metacycle was an iterative process much like a traditional product design process. Osterwalder & Pigner believe that the old way of thinking, where one makes a choice of the business model early in the entrepreneurial process, is outdated. Based on new thinking, they advocate using prototyping as a tool during the exploratory search for a business model. This was a very rich experience for the Metacycle team, as they evaluated the many value propositions they could offer. Examples of early prototypes that mapped out different scenarios can be seen in Appendix 15: Iterations of the Metacycle Business Model. As can be seen in some of the early scenarios, the team toyed with the idea of using advertising revenue on the website as a way to monetize the website. However, considering that Metacycle wants to present a new model for production and consumption in response the many problems associated with current models, the Metacycle team felt that selling advertising space to outside businesses should be avoided. As will be described below, the primary generator of revenue is through the sales of DDM parts that customers can purchase to combine with end-of-life products they have at home (such as the wall clock that combines a new clock casing with end-of-life markers).

The seven step scenario of how Metacycle functions is mapped out in Figure 30. The steps are: 1, a user posts a reuse concept and the design of any new components on the Metacycle website; 2, the Metacycle team selects the best concepts and does design development to optimize the part design for DDM; 3, another user sees the reuse concept online and places an order for the new parts to be fabricated and shipped to his home; 4, Metacycle sends the CAD file to be fabricated by the DDM company in its network that is closest to the customer; 5, the component is shipped the short distance to the purchasing customer; 6, the customer combines the new components with his end-of-life product; and 7, the originator of the idea is paid royalties for his or her contribution. The scenario map helps to understand how Metacycle works, but using Osterwalder & Pigneur's business model canvas to clearly articulate all elements of Metacycle's business model (Figure 31) is key to understanding all the elements at play. Each of the nine building blocks is described in detail in the following nine sections. It should be noted that www.metacycle.ca is not currently selling products online. This business model is a hypothetical scenario should the Metacycle team decide to actually start Metacycle as a company.

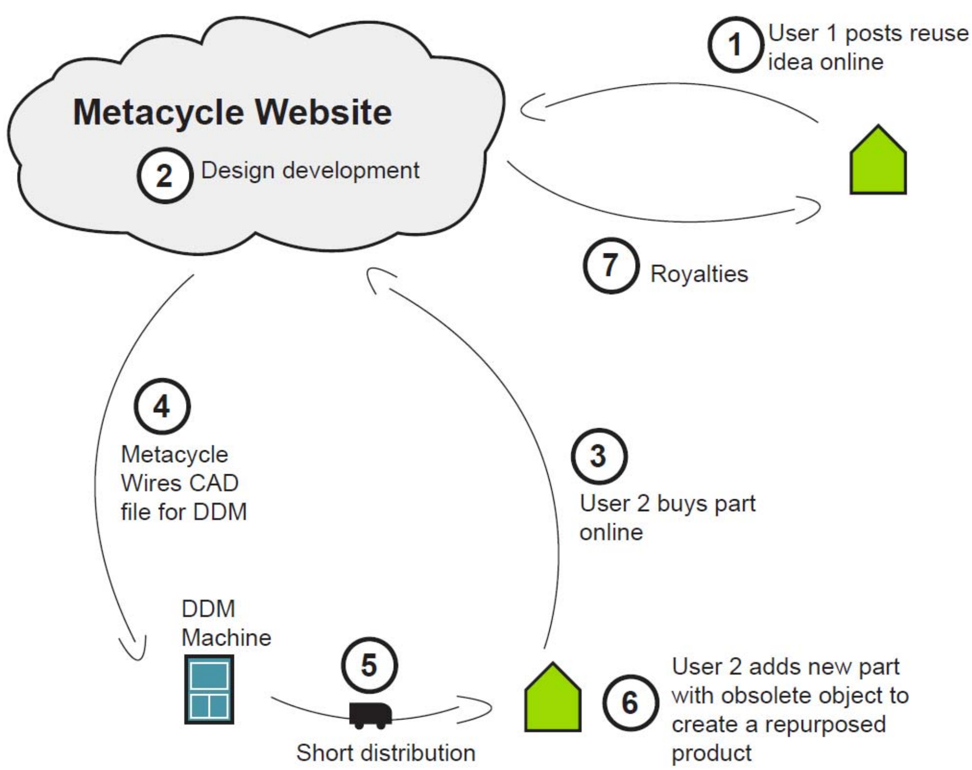

Figure 30: Metacycle Scenario Map

<table>
<tr><td rowspan="2">Key Partners

Designers posting ideas to the design lab.

Companies that offer rapid prototyping and DDM services.</td><td>Key Activities

Managing website.

Design development of ideas submitted to design lab.

Managing network of DDM services.</td><td rowspan="2">Value Proposition

Platform for designers to post ideas from which they can earn royalties.

Free access to database of DIY projects to reuse objects.

Online marketplace selling new DDM parts (e.g. Metacycle clock).</td><td>Customer Relationship

Self-service online</td><td rowspan="2">Customer Segments

Product designers looking to make royalties.

DIY community looking for projects that can be done at home.

Ecologically minded consumers looking to reuse objects.</td></tr>
<tr><td>Key Resources

International network of DDM machines.</td><td>Channels

metacycle.ca

Couriers</td></tr>
<tr><td colspan="3">Cost Structure

Key costs are fabricating parts and paying out royalties. Margins come from the difference between sale price, and fabrication and royalty costs.</td><td colspan="2">Revenue Streams

Revenues from sales of DDM manufactured parts.</td></tr>
</table>

Figure 31: Business Model Canvas for Metacycle

Value Proposition: Metacycle provides value on numerous levels. On one level, Metacycle is a platform where designers can post product concepts and designs that can earn them royalties. In this sense, Metacycle democratizes the design process by making it available to everyone. The barriers of high investments in product development and tooling costs are mitigated by the advantages of direct digital manufacturing. Through this model, anyone can design products that will be fabricated and sold to customers. Furthermore, Metacycle is a database of projects that the community can do themselves at home to reuse objects. In this sense, Metacycle has solutions for those not looking to spend money or buy new products. Lastly, Metacycle is an online store where customers can buy innovative products that are fabricated locally, almost anywhere in the world. Customers have the opportunity to buy into a new model of production and consumption.

Customer Segments: Metacycle customers can be considered a niche market as opposed to a mass market and there are three main customer segments for which Metacycle creates value. One segment is designers looking to develop products and make royalties on the sale of their product. This segment is a creative community with a certain level of design expertise. Another segment that Metacycle addresses is the community of people who enjoy DIY projects. This segment is targeted with the database of DIY projects that can be done at home to reuse objects. Lastly, Metacycle targets online consumers who are ecologically minded. This segment is the primary target market for sales of DDM products.

Channel: The channel Metacycle uses is the Metacycle website and the distribution network of couriers that deliver DDM products. The website is where customers get awareness about Metacycle products and services, make their evaluations, make their purchases, and get after-sales support. The channel also includes delivery of DDM products to the customer by courier from their local DDM facility.

Customer Relationship: The customer relationship can be defined as self-service, in the respect that the Metacycle experience is designed to be effortlessly understood by all visitors to the website. Interacting with the Metacycle website and making informed purchases of DDM products are also intended to be effortless.

Revenue Streams: The sole revenue stream for Metacycle is the revenue generated from selling DDM products. Product prices are fixed; however, depending where a customer is located, if the costs of fabricating the product at the local DDM facility are particularly high, these additional costs may need to be offset by an increase in the sale price for that location.

Key Activities: The three key activities for Metacycle are managing the website, doing design development of ideas submitted to the design lab, and managing the network of DDM services. Managing the website includes constantly reassessing the features and functionality of the site, running competitions and other events to keep community engagement high, and contributing to the Metacycle blog. Design development of the most promising concepts submitted to the website is a time intensive activity, and keeping up with the influx of ideas submitted will need to be managed. Lastly, managing the network of DDM partners is paramount to the Metacycle concept. The network needs to be constantly growing, so that the distance the products are shipped is increasingly minimized.

Key Resources: The one key resource for Metacycle, other than the website www.metacycle.ca, is the network of DDM machines that will fabricate all the products sold through the Metacycle website. Most facilities that have DDM machines have a variety of fabrication technologies that are normally used for rapid prototyping. The machines often used for DDM are fused deposition modeling (FDM) machines developed by the company, Stratasys, such as the ones pictured below in Figure 32.

Figure 32: Images of FDM Machines and a Batch of End Use Parts (Crump, 2008a)

Key Partners: There are two key partners in the Metacycle business model. The first is the network of designers that upload reuse ideas and product concepts to the website. Without these designers and creative thinkers, Metacycle would not have content to offer the community. Secondly, Metacycle has a network of key partners in the businesses that have agreed to fabricate products purchased through the Metacycle website. These businesses are accustomed to only providing prototyping services for their clients, so to accept business from Metacycle is to enter an entirely new market for them. The willingness for these "prototyping" companies to come on board with Metacycle as manufacturing partners is paramount to the success of Metacycle. This partnership could prove key to the prototyping companies' own success as well, by generating an entirely new revenue stream.

Cost Structure: Metacycle's key cost is paying prototyping companies to use DDM to fabricate parts that have been purchased on the website. Another key cost is paying out royalties to designers whose products are sold online on metacycle.ca. The cornerstone of Metacycle's cost structure is that all key costs are variable costs, meaning initial investment and risk are very low. Metacycle's margins come from the difference between the per-unit sale price of products sold, and the combination of per unit fabricating cost and royalty fee. Despite the variable nature of these costs, the nature of Metacycle's manufacturing is high cost, which is covered by a premium price. The custom nature of the design, the novelty of the fabrication process, and the ecological benefits of the product, all add value and may justify the premium price for the customer.

7.5 Product Design and Business Model Relationships at Metacycle

The following four tables show the business model and product design relationships at Metacycle. The same methodology is used as in the previous two cases.

	Reused Materials
CVP	Designing products with reused materials is an **essential** part of the customer value proposition (DABM because reuse was a driver in developing the business).
Cost Structure	Reusing materials is **vital** to keeping per unit costs down and making the Metacycle cost structure viable (DSBM).
Key Resources	Combining reused materials with DDM parts is **vital** to the merits of using DDM in a sustainable business model (DSBM). Customization associated with DDM manufacturing **significantly supports** designs that combine new parts and reused materials (BMSD).
Key Partners	All products are initially designed by a designer in the community, a key partner of Metacycle, and so key partners are **essential** to the existence all designs including those that reuse materials (BMAD).
Customer Segment	Designs that reuse materials **significantly contribute** to targeting DIY and ecologically minded segments (DABM).
Revenue Streams	The more material reused, the more value added to customers, which stands to **contribute** to increased sales and thus higher revenue streams (DSBM).

Table XV: Reused Materials / Business Model Relationships

	Form
Key Activities	Designs are crowd sourced by designers who may not understand all the design requirements of DDM, so design development of the formal aspects is **essential** to the feasibility of the designs (DABM and BMSD).
Key Partners	All products are initially designed by a designer in the community, a key partner of Metacycle, and so key partners are **essential** to the existence of any design and its form (BMAD). The community of non-professional designers is also a **significant factor** in the fact that most forms need design development (BMAD).
Cost Structure	Forms that minimize material use, machine time, and the need for support material, **significantly contribute** to the economic viability of Metacycle's cost structure (DSBM).
Key Resources	The network of DDM machines, Metacycle's key resource, has a **major impact** on the formal elements of the product designs (BMAD). Furthermore, the better the forms are suited for this fabrication technology, the more they **contribute** to the success of the business (DSBM).
Customer Relationship	Products are purchased online, so forms that are easy to understand and appreciate online **helps support** the self-service customer relationship of the business model (DSBM).

Table XVI: Form / Business Model Relationships

	Aesthetics
Key Partners	All products are initially designed by a designer in the community, a key partner of Metacycle, and so key partners are **essential** to the existence of any design and its aesthetics (BMAD).
Key Resources	The use of DDM machines plays a **significant role** in the aesthetic outcome of Metacycle products (BMAD).
Key Activities	Design development, a key activity of the Metacycle business model, **significantly affects** and hopefully improves the aesthetic qualities of the products (BMSD).
Revenue Streams	Products with an aesthetic that creates a positive emotional response in customers stand to **strongly support** revenue streams (DSBM).
Customer Relationship	Products are purchased online so an aesthetic that is easy to understand and appreciate just by seeing it online **helps support** the self-service customer relationship of the business model (DSBM).
Channel	Metacycle's channel, www.metacycle.ca, is in a position to **affect** the aesthetic standard of submitted designs through the website's own design and the products that it promotes, features, and awards (BMSD).

Table XVII: Aesthetic / Business Model Relationships

	DDM Materials
Key Resources	The network of DDM machines, a key resource which fabricates all parts, plays a **vital role** in defining material choices (BMAD).
Key Partners	The network of DDM companies with which Metacycle partners offer different material choices and play an **essential role** in defining which materials are available (BMAD).
Key Activities	Design development by the Metacycle team stands to **significantly affect** material choices due to Metacycle's experience with designing for DDM (BMSD).
Cost Structure	Material choices strongly affect the costs associated with part fabrication (DABM). Designing parts that can be made from inexpensive materials **strongly supports** a viable cost structure (DSBM).
Channel	The Metacycle website can inform the design community about DDM material options and considerations which can **affect** the feasibility of the submitted designs (BMSD).

Table XVIII: DDM Materials / Business Model Relationships

7.6 Results and Interpretation

After looking through the tables that identify the many relationships between aspects of Metacycle's product design and its business model, the following results can be noted. Of the 36 possible relationships that could come from looking at how each of the 4 main aspects of product design relates to each of the 9 building blocks, 22 relationships were identified. Of those 22 relationships, 9 are identified as vital relationships; 8 are identified as significant relationships; and 5 are identified as incidental relationships where one side is only one of many factors that support or affect the other side. Furthermore, within those 22 relationships, there are 9 instances where design supports the business model (DSBM); 6 instances where the business model supports design (BMSD); 4 are instances where design affects the business model (DABM) and 8 instances where the business model affects design (BMAD). These instances add up to 27, since some of the 21 relationships are multifaceted. Table XIX summarizes where the relationships exist and denotes the level of significance of each relationship.

		Aspects of Product Design			
		Reused Materials	DDM part Form Factor	DDM Part Aesthetic	DDM Materials
Business Model Building Blocks	CVP				
	Customer Relationship				
	Channel				
	Customer Segment				
	Key Partners				
	Key Resources				
	Key Activities				
	Cost Structure				
	Revenue Streams				

Table XIX: Significance Level of Product Design and Business Model Relationships at Metacycle

Looking at the results, a picture emerges of a sustainability driven company where product design is inextricably connected to its business model. Each aspect of the product design at Metacycle has a vital, a significant, and an incidental relationship with different building blocks of the business model. Furthermore, there is a comfortable balance between relationships where design supports the business model and others where the business model supports design. Highlighting the vital relationships that exist between product design and the Metacycle business model stands to help identify the defining elements of this relationship.

On the product design axis, reusing materials has a vital relationship with four of the business model building blocks and so stands out as one of these defining elements. Reusing materials was one of the founding principles of the Metacycle project so it was a driver in defining the customer value proposition. Also, using reused materials for some components of a product is often the only way to keep cost at a viable level, and also to keep environmental impacts associated with production less than they would be with a more traditional production model.

On the business model axis, the key partners building block has the most vital relationships with product design. The two key partners, the community of contributing designers and the network of DDM companies, play a vital role in multiple aspects of product design. Evidently, as the product designers, the community plays a vital role in almost all aspects of product design. Furthermore, the network of DDM companies is essential to fabrication, and all design decisions that are affected by using DDM as the fabrication technology.

Having these elements emerge as the most vital make perfect sense, in the respect that through these relationships, the whole Metacycle concept is accurately described as a platform where a community of designers design products that reuse materials with some components that can be fabricated by a network of DDM companies. A characteristic of this methodology seems to be that the columns and rows that have the most relationships, and particularly the most vital relationships, highlight the defining elements of a business and its product design.

There are a few significant relationships that are also worth noting. Many manufacturing companies would have business models that are not so significantly affected by the company's fabrication processes. In Metacycle's case, the fabrication process and the associated network of DDM machines that fabricate Metacycle products, is integral to its business model and has ripple effects through multiple relationships. For example, the DDM significantly affects the new part form by affording certain liberties and imposing certain limitations. Given the novel approach of using DDM for consumer products, design decisions can greatly support the success of this part of the business model. For example, DDM has a much higher per unit cost than injection moulding, so rigorous design strategies must be adopted to reduce costly variables, such as material volume, fabrication time, and the need for support material. One strategy that was used to eliminate the need for support material in the design of the Metacycle wall clock was to make the marker holes tear drop shaped. The teardrop shape held the markers in place just as well as the round hole, however the teardrop shape used a manageable overhang angle (Figure 29). The result was a design that used less material, was faster to produce, and needed no support material. These design strategies also have huge environmental benefits. Minimizing machine time means less energy use, less material means less raw material extraction and processing, and no support material does away with the chemical bath needed to remove support material.

Lastly, there are some incidental relationships that provide some insight into the nature of relationships between business models and product design. Metacycle's channel is www.metacycle.ca and its customer relationship is based on self-service. This is a common combination for businesses that exist solely online. Metacycle's product designs can support these aspects of its business model by taking this self-serve experience into consideration at the design stage. Designs optimized for this online channel and for a self-serve customer relationship would be simple designs whose features and merits are easily understood through descriptions, images, and possibly video. In terms of the business model supporting design, Metacycle's website can be a platform to promote the kind of design standards expected from the community. The website can provide design guidelines as well as promote, feature, and award designs that embody the aesthetic that Metacycle anticipates.

7.7 Metacycle Case Conclusion

Metacycle is a project that began with the question of how might new fabrication technologies help to give a second life to end-of-life objects. This problem is simultaneously a design problem and a business model problem. It is a business model problem on one hand, because for the solution to have any significant impact, it would have to be economically self-sustaining. On the other hand, as the researchers began to look at the potential of direct digital manufacturing, they realized that the solution might involve a novel approach to connecting design, manufacturing, distribution, and consumption. The way these elements would be connected would inevitably play a large role in defining the business model that Metacycle should adopt.

This case provided a perfect opportunity to carry out an action research where product design and business model design could be carried out simultaneously. The team prototyped different scenarios that gave form to the business model and they prototyped product designs. Through the design competition, many product concepts were submitted, and the Metacycle design team refined and developed the most promising concept. By having developed a product alongside the Metacycle business model, the Business model building blocks and product design aspects could be identified and the relationships between them identified. As shown above, the business model and product design of Metacycle are highly interdependent.

There are numerous relationships between product design and business models that characterize Metacycle, both where design supports the business model and where the business model supports design. The high cost of DDM means that Metacycle's cost structure needs to balance high fabrication costs with reduced costs elsewhere. Using the online store and distributed DDM, Metacycle can reduce costs associated with a retail space or with longer distance transportation. Design supports Metacycle's cost structure by reducing fabrication costs. The two main ways that design can do this is through combining parts with reused materials, and through minimizing material use, machine time, and the need for support material. Design also supports the business model through forms that are structurally suited for DDM. The better suited the designs are for the network of DDM machines, the more successful the Metacycle business model will be.

In terms of the business model supporting design, there are numerous noteworthy relationships. The fact that the design community is involved in all design is a primary way that the business model supports design. The design development by Metacycle designers is another way the business model supports design. Lastly, the fact that DDM is appropriate for highly customizable designs strongly supports the ability for designs to be combined with reused materials. For example, in the Metacycle wall clock, the hole sizes can be customized for whichever pens or markers a customer wishes to reuse.

A life-cycle analysis of the product developed by Metacycle was instrumental in understanding the ecological benefits and limitations of the Metacycle business model. In fact, a key learning from the Metacycle case is how the life cycle of a given product can be highly affected by the business model of the company that manufactures, sells, and distributes the product. In each scenario that prototyped how the Metacycle concept might work, the researchers could see very specific differences in the life cycle of the products. For example, would the reused materials be collected by Metacycle and then repurposed and sold, or would customers use materials they had at home; would Metacycle sell products in stores or would they be delivered directly to customers; would Metacycle target consumers, businesses or both? All of these factors would alter the life cycle of the products that Metacycle developed and sold. The LCA also highlighted which stages of a Metacycle product cause the most environmental impacts. Ironically, DDM production is directly responsible for the most impacts, but has indirect consequences that reduce environmental impacts, such as reduced packaging and transportation distance. Design strategies that minimize material use, machine time, and support material are vital to the ecological merits of the Metacycle business model.

Chapter 8. Case Study Discussion

8.1 Answers to Research Questions

The three case studies reveal some detailed information about the relationship between product design and business models in the context of sustainability. The primary research question of this thesis is, "In what ways are product design and business models related in organizations where sustainability is a top priority?". On a general level, relationships between aspects of product design and business models can be classified into two categories: design can affect the business model and the business model can affect design. Furthermore, relationships can be classified by how strong they are, namely vital, significant, or incidental. Ultimately, all relationships described in the tables of the three case studies are examples of how product design and business models are related in organizations where sustainability is a top priority. Sometimes, those relationships are not just one side affecting the other, but one side actually supporting or contributing to the success of the other. The first two secondary research questions ask whether product design can contribute to the success of a business model and whether elements of a business model can contribute to the success of product design. As can be seen in the conclusions of each case, all three cases show that product design can contribute to the success of a business model, and that elements of the business model can contribute to the success of product design. All identified relationships are summarized into six key insights outlined in the following section.

The three cases have also uncovered numerous benefits and limitations of considering business model and product innovation simultaneously. Because only three cases have been studied, it should not be assumed that these benefits and limitations are universal. The benefits in the Better Place case are that it helped the company offer a CVP that could only be achieved through addressing both the product level and the business model level. Also, the company could get the right partners on board that simultaneously contribute to the business model and the product design. For Interface, so many of the sustainability initiatives that shifted the business model had significant implications for product design. The level of efficiencies Interface has achieved could not have been reached without the synergy of optimizing design for each business model innovation and vice versa. The Metacycle case shows that designing a sustainable life cycle for a product can require designing a business model. By designing both simultaneously, the life cycle could be optimized for reducing environmental impacts. Furthermore, the designs could be optimized for the manufacturing process. Reviewing the benefits of addressing product innovation and business model innovation simultaneously, there seems to be an increased potential for a radical shift in how a company creates sustainable value in a market or an industry.

The limitations of this process, however, are equally important. The main limitation is the financial risk associated with such an endeavour. Both Better Place and Interface have invested hundreds of millions of dollars in trying to leverage the potential of innovating products and business models simultaneously. Incremental innovation is far more predictable and far less costly. Another limitation, one encountered by Interface, is that it can be difficult to get all employees on board. Employees value the security of their jobs and convincing them to take big risks on shifts in the pillars of the company took relentless speaking engagements from CEO, Ray Anderson. Another limitation encountered in all three cases is the difficulty of prototyping business models. Better Place is using Israel and Denmark as pilot countries, but the concept will not be able to be fully validated until a few years of steady growth is seen at the company. Interface had no choice but to develop the whole service business before rolling it out, only to discover that in the longer term it was not viable. Lastly, Metacycle used an LCA to prototype the environmental merits of the company concept, but no actual business has been started yet. The concept can only be fully tested by actually launching the company. Only then will the success or failure of the concept be fully known.

It should be noted that this paper is not trying to prove that product design and business model innovation should always be done together to achieve more sustainable solutions. This research is simply looking at three particular cases where sustainability is a priority, and trying to highlight the kinds of relationships that can theoretically exist and how they mutually impact one another. The major relationships and learnings from the three cases have been distilled into six key insights, outlined below.

8.2 Six Key Insights

Insight 1: There *are* universally applicable relationships.

Looking at the three cases, design supporting the business model is a common relationship. This is due to the multiple ways that elements of product design always support the business model building blocks. When companies develop a product, the product is always a component of the customer value proposition in some capacity. Even if the company develops products that will be leased and not sold, the CVP is about providing access to that product. For any organization, the better a product design is from the user's perspective, the more that design will be supporting the CVP. Furthermore, if the environmental merits of a product are part of the CVP, any design decisions that reduce environmental impacts, such as selection of low impact materials and reduction of material use, are also supporting the CVP. Design decisions are also always connected to the cost structure and revenue streams. All design decisions that reduce cost contribute to supporting how the business will manage its costs. Likewise, the more successful a design is from a user's perspective, the more the design will support generating revenue streams. All three cases show how design can support the cost structure and the revenue stream.

This last point leads to another universal relationship: the customer segment always affects product design. Product design needs to consider the product's user and target market. This relationship can be seen playing out clearly in all three cases where the mass market for Better Place, the commercial and institutional segment for Interface, and the DIY and ecologically minded segments for Metacycle, all affect product design in the respective companies.

Insight 2: Discontinuous design innovation can play a vital role in sustainability.

Another common thread that runs through all three cases is that there is a significant or discontinuous design innovation that is highly related to the business model and plays a vital role in the viability and sustainability of each company. In the Better Place case, the swappable battery / swap station is the significant innovation needed to create a CVP that could compete with a combustion engine car on convenience. The main connection to the business model is the revenue stream innovation that makes a swappable battery possible. For Interface, the carpet tile form factor is the significant design innovation that made the switch to a service model possible. Despite the service model not working, the carpet tiles are still a key factor in the efficiencies and sustainability of the business. In the Metacycle case, repurposing objects is the radical change that makes it possible to use DDM for Metacycle products. Repurposing greatly reduces cost, new material needed, fabrication time, and packaging associated with Metacycle products. All three cases have a significant design innovation that is integral to the sustainable business model. Companies looking to become more sustainable could benefit from looking for ways that discontinuous product innovation could be combined with business model innovation.

Insight 3: Sustainability is an emergent quality of a business model.

In systems thinking, a system is known to be made up of individual interrelating elements that are considered to exist on a level below the system. The ability for a system to have qualities that may not apply to any of its individual elements is a function of this hierarchal nature of systems. Such qualities are called emergent qualities. Looking at the three cases systemically helps to understand sustainability as an emergent quality of a business model, in the respect that each element of the business model may not be inherently sustainable. In the Better Place case, elements of the business model such as the charging infrastructure, the partnership with Renault-Nissan, the batteries, and the leasing model may not be inherently more sustainable. But when all elements come together on the systems level, the system itself can be evaluated for its sustainability merit. In the case of Metacycle, DDM is not inherently a more sustainable fabrication method. In fact it uses significantly more energy. However, within the system of distributed manufacturing, reduced transportation, and renewably sourced energy, the system itself becomes more sustainable. This is another example of how the sustainability of a business model is an emergent property.

Insight 4: Key partnerships support systems level integration.

Key partners can help a company design new products and prevent it from having to re-inventing the wheel, but perhaps most importantly they can create the systems level integration necessary for more sustainable solutions. In both the Better Place and Metacycle cases, key partners have vital relationships with product design and sustainability. For Better Place, partnerships with manufacturers, renewable energy companies, and governments help the company offer a broad, integrated, and sustainable CVP, while staying focused on its core competency of developing and managing the recharging infrastructure. Metacycle focuses on its core competencies of design refinement for DDM and managing the website, while key partnerships with DDM companies and user generated content creators help it offer diverse products and an integrated sustainable production network.

Insight 5: A service revenue model has significant benefits and limitations.

The service-based revenue model implemented by Better Place, where the company offers access to a charging infrastructure and swappable batteries for a monthly fee, is a key element of the company's design innovation. Knowing that they don't own the battery in their electric car allows customers to feel comfortable with swapping it for a fully charged one, should the need arise. Furthermore, the initial purchase price of the car is reduced by $10,000 and Better Place can upgrade its battery technology as needed, without the user having to buy a new car. All things considered, a service-based revenue model for Better Place is a key catalyst of design innovations and an improved customer experience.

Switching to a service-based model can make a business more competitive and more sustainable. When Interface attempted to shift their entire business to a service-based revenue model, many design innovations increased efficiencies related to providing that service. However, due to petrol industry subsidies, tax laws, low carpet tile salvage value, and other reasons, the Evergreen Service Agreement did not pan out for Interface. Even though the service model was not appropriate for Interface, sustainability was fully integrated into the business model through what Interface refers to as the seven faces of sustainability. The design innovations initially thought of as benefitting the service model still offered huge advantages to the sustainable business model.

Insight 6: Design innovation can help drive the shift to renewable energy.

In one respect, product design can support the shift to renewable energy by shifting the type of energy that is demanded. Better Place switches the personal transportation energy source from gasoline to electricity which can be generated from renewable sources (hydro, solar, wind, etc.) and uses margins in its cost structure to pay the premiums for renewable energy. This is similar to Metacycle which transitions from a model where the impacts are focused in the transportation stage, to one where the impacts are more focused in the production stage. Production uses electricity, so sourcing production energy through renewable sources is far easier than transitioning delivery trucks to electricity.

In another respect, design can support the shift to renewable energy by supporting the cost structure. Renewable energy is currently more expensive than more traditional energy sources, and so finding the money to pay the premiums for renewable energy can be difficult. The massive efficiencies and cost savings enabled by design innovations at Interface help it pay for renewable energy in its factories. Likewise, the cost parity between powering a car for one kilometer with electricity compared to gas allows Better Place to include premiums for renewable energy in the company's cost structure.

8.3 Looking Forward

This research is grounded in a pragmatist paradigm and intends to make clear connections between the theory and praxis of problem solving. Part of this research involved a research-in-action methodology where the researcher actively engaged in the problem solving space. Likewise, taking action is a large part of the purpose of this study, in that the main purpose of this research is to help designers, environmentalists, managers, executives, or any other stakeholder, leverage both business model innovation and product innovation to create sustainable solutions. In fact, following the same methodology used in this thesis could be an effective way to bring an organization to thinking more systemically about innovation in its own context.

An enterprise or an organization can create its own relationship matrix. By filling in the business model canvas and identifying some key aspects of the product design, a team could create a table similar to the tables used in each case. With the product design attributes on one axis and the business model canvas building blocks on the other, filling in the matrix can identify relationships that had not been thought of otherwise, and identify new opportunities for innovation. One could consider how the relationships would change if an element of the business model changed, or if an aspect of the product design changed. Furthermore, highlighting the most vital relationships, as was done in this research, is a good way to identify the vital aspects of one's product design and of the business model, and why.

For example, the column or row that has the most vital relationships or the most total relationships points to the particular product design aspect or the particular business model building block that is the most influential.

As another layer of analysis, a team could go through the eight key insights about product design and business model relationships to see how they apply to one's own organization. A team could ask how the universal relationships apply; how a discontinuous product innovation could affect the business model; how systems thinking could support sustainability; what role partnerships could play; how servicizing could create opportunities; and if there is an opportunity to catalyze renewable energy demand.

In an earlier chapter, a lot of emphasis was placed on the growing trend of business leaders advocating the integration of design processes and methodologies into business problem solving. The growing trend for design firms to be awarded business strategy and innovation management contracts was also presented. It is easy to see these two trends converging on the type of problem solving and innovation that this methodology proposes to facilitate. Presumably, as these trends mature, understanding the relationships and methodology presented in this research will be increasingly in demand. Living in what Osterwalder & Pigneur call the business model generation, defined by radical shifts in information technology and the way organizations can create value, we are no longer just designing with the opportunities and constraints of materials and production processes. We are also designing within the opportunities and constraints of business models.

There is a huge opportunity for designers to think of optimizing products for business models. This research begins to touch on this subject, but there is definitely further research that would be beneficial on this topic. Of course, the needs-based approach, which is so important to sustainable and human-centered design should never be ignored. The fact that business models are also needs-based suggests that optimizing designs for business models would be well aligned with a needs-based design approach.

Another area of research that could be pertinent is related to the relationship matrix. The business model building blocks along the vertical axis are well defined from the business model canvas. However, the product aspects in this research have been defined differently in each case. Could there be a model used to define all possible aspects of a product or perhaps a sustainable product? For example, how could the relationship matrix be used if the business model building blocks occupied one axis while the eight sustainable design strategies from

Brezet and Hemel (1997) occupied the other? What could those relationships say about sustainable design and business models?

Lastly, the concept of a business model was developed to map out the logic that defines how a business creates, delivers, and captures value. Further research could be done exploring the benefits and limitations of applying the business model concept to different scales of an organization. Considering the large scale of many international corporations today, one could presumably define the business model of the global organization one way, yet a subsidiary or a branch of that organization could be defined with a totally different business model. Taking that premise one step further, could one define a business model for a particular department or even an individual product? Perhaps an understanding of a product focused business model could be used to manage the business factors of any product design project.

Chapter 9. General Conclusion

Multiple drivers in the fields of product design, business models, and sustainability, are making the intersection between these three fields increasingly relevant. For example, in the field of sustainability, the paradigm of unlimited economic growth is negating current efforts to curb the environmental impacts of providing goods and services to society. The industrial system at the heart of the economy is having dire negative consequences to all living habitats on earth. To keep up with population growth and the growing worldwide per capita demand for goods and services, increased efficiencies by many factors will have to be realized to reduce ecological impacts. Meanwhile, the field of industrial design is expanding its boundaries to include system and service design. Design processes and methodologies, celebrated for delivering innovation, are being recognised as having value to business problems. Designers are applying their expertise to business contexts while business leaders are scrambling to learn how to think like designers. Furthermore, information technology is revolutionizing the business landscape and certain researchers have developed a clearly articulated meta-model, called a business model, for depicting the logic that organizations use to create, deliver, and capture value. At the intersection of these drivers is the opportunity to understand the relationships that exist between product design and business models to help decision makers develop more sustainable solutions.

To answer the question "In what ways are business models and product design related in organizations where sustainability is a top priority?", this research has carefully analysed three cases: Better Place, a company that has developed a charging infrastructure for electric cars; Interface Inc., a commercial carpet tile manufacturer; and Metacycle, a company concept developed by a team of design researchers. Each case study describes the company and the role that sustainability plays in the company, describes the details of product design at that company, and then uses the business model canvas, developed by Osterwalder & Pigneur (2009) to define the company's business model. Each aspect of the product design is then correlated to each element of the business model, and all existing relationships are articulated in a matrix, labeled by direction and strength of influence. Finally, the relationships identified in each case are summarized and interpreted.

The results show that in the context of sustainability, product design and the business model can be inextricably connected. Product design can support or contribute to the success of the business model, and the business model can support or contribute to the success of product design. Conducting business model innovation and product innovation simultaneously does have numerous benefits as well as limitations. Namely, there can be large payouts in the form of creating sustainable value, uncovering opportunities, and increasing efficiencies many fold, however the risks and cost of such a process are often very high. The results can be summarized in six key insights:

1. There are universally applicable relationships.
2. Discontinuous design innovation can play a vital role in sustainability.
3. Sustainability is an emergent quality of a business model.
4. Key partnerships support systems level integration.
5. A service revenue model has significant benefits and limitations.
6. Design innovation can help drive the shift to renewable energy.

Applying the methodology and lessons of this research to one's own organization could help to uncover new opportunities for innovation. This research, by helping to understand and define how these areas are inextricably related and interdependent, will hopefully inspire further research on the subject, and help others to use the intersection between product innovation and business model innovation to solve complex problems - social, environmental, or otherwise. Perhaps through solving such problems, society's needs can be met in balance with careful consideration for tomorrow's child, who will one day inherit both the natural *and* designed systems of planet earth.

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Appendices

Appendix 1: The Role of Abundance, Asia and Automation in Shifting the Information Age Paradigm

Abundance has over satisfied the needs of millions, accelerating individuals' search for meaning in products, services and experiences. Asia's contribution to the global workforce is swallowing up many of the white collar jobs associated with the Information Age, with 4.5 million white collar jobs expected to be outsourced from North America and Europe to Asia by 2015. Lastly, automation is replacing much of the work associated with the information age as computers and their software are able to do it better, faster and cheaper. The western economy and society now will become increasingly built on the creative, empathic and big-picture capabilities of the Conceptual Age – skills that create meaning, that can't be outsourced and that can't be automated (Pink, 2005).

Appendix 2: Buchanan's Four Orders of Design

Buchanan's four orders of design are communication, construction, strategic planning and systemic integration. The first of these areas is the design of symbolic and visual communications encompassing all visual media; the second area is the design of all products and material objects; the third area is the design of activities and organized services, which includes the traditional management concern for logistics, combining physical resources, instrumentalities, and human beings in efficient sequences and schedules to reach specified objectives; the fourth area is the design of complex systems or environments for living, working, playing, and learning (Buchanan, 1992).

Appendix 3: Details of the Design Process

A designer's sequence of activities is called a design process (Simon, 1969). There have been countless attempts by design scholars and practitioners to develop a model or map of the design process. Some focus on simply presenting various steps common in the design process while others focus more on presenting what they believe is a more appropriate pattern of activities (Cross, 2000). Despite the diversity of models of the design process, there are numerous common characteristics.

Primarily, the design process can be considered to have some general agreed upon chronological steps. In Figure 33, Nigel Cross presents a very basic four stage model consisting of exploration, generation, evaluation and communication. Herbert Simon uses a seven stage model as an example of a design process in *The Sciences of The Artificial* with the steps being: define, research, ideate, prototype, choose, implement, and learn (Simon, 1969). Ultimately, all stages can be thought of as falling into one of three general spaces with vague, overlapping edges. The first space is the front end of design which includes such activities as problem definition, research, strategy and inspiration. The second space is about exploring options through brainstorming, ideation, sketching and prototyping and testing ideas. The third space is about execution and consists of such activities as detailed design development, communication and creating deliverables. Tim Brown refers to these three spaces as inspiration, ideation and implementation (T. Brown, 2008).

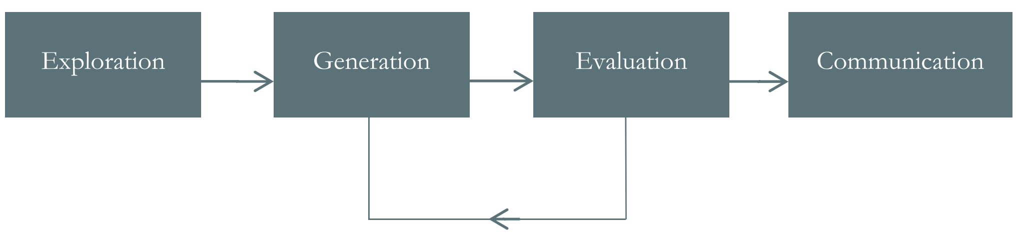


Figure 33: Four-Stage Design Process (Cross, 2000)

A second common theme is that generally the design process moves from the very broad to the very specific as it deals with problems that can have infinite possible solutions. Such is the nature of design problems. Design Problems are wicked problems in that they have no single correct solution, only good solutions and bad solutions (Buchanan, 1992). And dealing with wicked problems means that "the process is *heuristic*: using previous experience, general guidelines and rules of thumb that lead in what the designer hopes is the right direction, but with no guarantee of success" (Cross, 2000, p. 29). By nature, the design process demands that designers be comfortable with the ambiguity that defines the early stages of the design process. A funnel shape is often used as an analogy of this aspect of the design process. As one moves through the process chronologically, the goal is to move from many potential solutions, to a few promising solutions, to one very refined feasible, viable and desirable solution. Divergent thinking that leads to creating many ideas creates a wide opening of the funnel with many potential solutions, while convergent thinking is the type of thinking used to get to the narrow channel that represents the most desirable, viable and feasible solution (T. Brown, 2009).

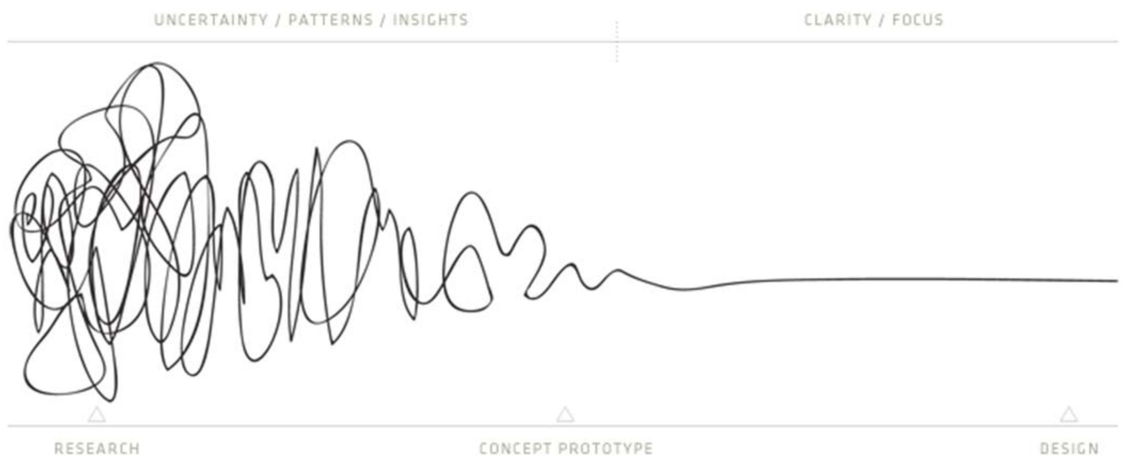


Figure 34: A Funnel Shaped Depiction of the Design Process (Newman, 2011)

Another key aspect to the design process is that it is iterative. As a design team progresses through a project, no stage is entirely complete. As wicked problems have no clearly defined finished point (Buchanan, 1992), such is the nature of each stage of the design process. As a team moves forward in a project, new information is revealed on the nature of the work performed in the current and previous stages. Donald Schön recognizes this "talk-back" from the design activity as an indicator of a good design process:

> In a good process of design, this conversation with the situation is reflective. In answer to the situation's back-talk, the designer reflects-in-action on the construction of the problem, the strategies of action, or the model of the phenomena, which have been implicit in his moves. (Schön, 1983, p. 79)

But the iterative nature of the design process is more than just sometimes retracing ones steps. Stages such as ideation, prototyping, testing, and learning are intended to be performed in multiple iterative cycles, especially in the second general space of the design process. The design process taught at the Hasso Platner Institute of Design at Stanford, is represented in

Figure 35, and makes clear the importance of moving forward and backward through the steps as necessary. The iterative nature of the design process is also depicted by the feedback loop between generation and evaluation in Figure 33.

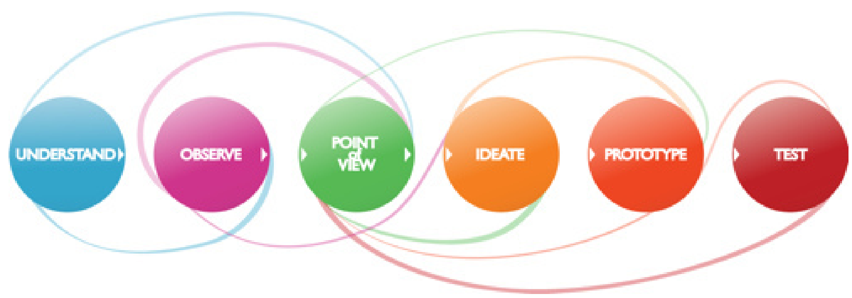


Figure 35: Design Process (Hasso Platner Institute of Design at Stanford, 2009)

The design process is a unique creative problem solving process. Very different from the scientific method, it is commonly used to solve wicked problems that have no single correct solution, the way, for example, an algebra problem does. This process is starting to be thought of has having enormous value, even outside the field of the traditional design project.

Appendix 4: Sustainable Design Strategies and Sub Strategies

Sustainable Design Strategy	Sub Strategies
Strategy 0: New Concept Development Addressed before any actual product design decisions are made. The focus is not on a physical product but on the function of a product system and the way it fulfills a need.	• **Dematerialization** – replacing a material product with an immaterial substitute which fulfills the same need • **Shared use of the product** – needs are met with fewer products • **Integration of functions** – one object can answer numerous needs • **Functional optimization** – avoiding superfluous components
Strategy 1: Selection of Low Impact Materials Very contingent on the life cycle of the product in that the appropriateness of materials is context relevant.	• **Cleaner Materials** – some materials cause hazardous emissions during production or when dumped • **Renewable materials** – material sources should be replenished naturally • **Recycled materials** – use materials that have been in products before when possible • **Recyclable materials** – more effective when collection systems are anticipated
Strategy 2: Reduction of Material Usage Suggests using the least amount of material possible by proposing lean yet strong product designs.	• **Reduction of weight** – lessens environmental impacts associated with distribution • **Reduction in (transport) volume** – decreases the needed transport facilities
Strategy 3: Optimization of Production Techniques Asserts that production techniques should minimize auxiliary materials and energy needed and minimize energy use.	• **Alternative production techniques** – new techniques can be invented to address certain specific production needs • **Fewer production steps** – simple production processes can be less harmful • **Lower/cleaner energy consumption** – in the production process • **Less production waste** – production efficiency should be maximized to minimize waste and emissions • **Fewer cleaner production consumables** – minimize the operational materials usage
Strategy 4: Optimization of the Distribution System Ensures that the product is transported to the retailer from the factory in the most ecologically efficient manner possible.	• **Less/cleaner/reusable packaging** – minimize impacts associated with the packaging • **Energy-efficient transport mode** • **Energy-efficient logistics** – loading and distribution logistics can be optimized
Strategy 5: Reducing Impact During Use Looks at reducing the consumables (such as energy, water, detergent, batteries etc.) associated with the use of a product.	• **Lower energy consumption** – and evaluate the efficiency of the energy related components • **Cleaner energy sources** – favour renewable energy • **Fewer consumables needed** – make the product as autonomous as possible • **Cleaner consumables** – chose benign possibilities for those that are needed • **Reduce wastage of energy and other consumables** – encourage efficient usage of the product
Strategy 6: Optimization of Initial Lifetime Has the goal of making the product useful for the longest possible time, through prolonging the technical, aesthetic and initial lifetimes of a product.	• **Reliability and durability** – make a good quality product • **Easier maintenance and repair** – ensures necessary maintenance on time • **Modular product structure** – facilitates the revitalization of a broken or unwanted product • **Classic design** – avoid trendy designs • **Stronger product-user relation** – a user that cares for its product will respect and maintain the product properly
Strategy 7: Optimization of End-of-life System Requires proper waste-management and end of life treatment. Material cycles should be closed when possible or otherwise disposed of in the appropriate way.	• **Reuse of product** – the more a product remains in its original form, the more environmental merit is achieved • **Remanufacturing/refurbishing** – subassemblies can be reused in new manufacturing processes • **Recycling of materials** –consider take-back and recycling infrastructure to ensure high percentage of recycling success. • **Safer incineration** – thermal recycling from incinerated products can be beneficial if done safely

(Adapted from Brezet & Hemel, 1997).

Appendix 5: The Four Tools of Eco-Efficiency

The four actual tools that are used by firms to achieve greater eco-efficiency are environmental management systems, life cycle assessment, ecodesign and environmental supply chain management (Five Winds International, 2000). Environmental management systems are the organizational structures and procedures for managing an organization's environmental affairs. Life cycle assessment is a decision making tool to asses an activity or a product's environmental impact over the course of its entire lifetime, considering resource extraction, manufacturing, use, distribution and end-of-life treatment. In the context of eco-efficiency, ecodesign is the integration of design for the environment strategies into product design. Lastly environmental supply chain management is an in depth consideration of all goods and services purchased that go into running the business.

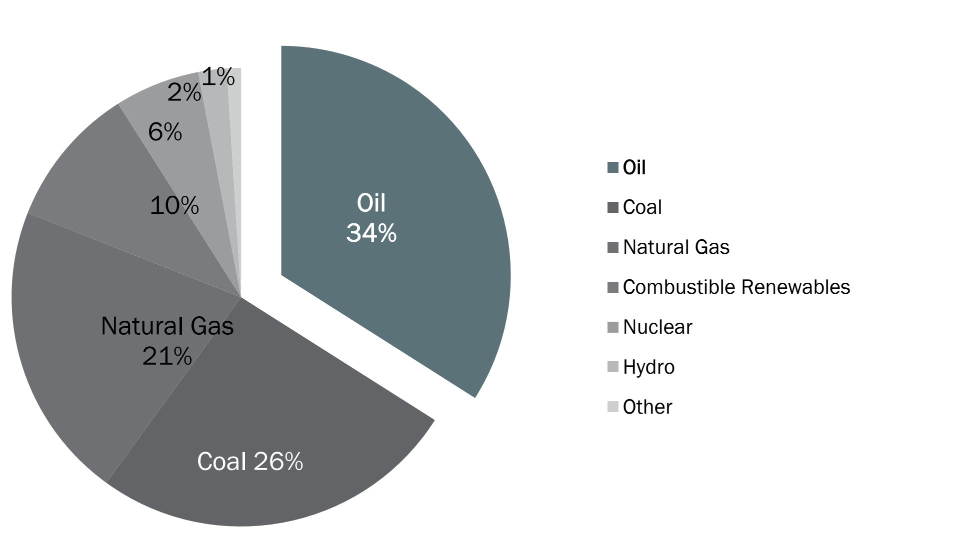
Appendix 6: Shai Agassi's Background

From the moment he first got a computer when he was 14 years old, Agassi devoted his life to software development. He graduated from Technion, the Israel Institute of Technology, with a Bachelor's degree in computer science in 1990 and together with his father Agassi founded numerous software companies including Quicksoft Ltd., TopManage and Quicksoft Media. The company that Agassi was previously most well-known for founding is TopTier Software, which developed the technology and software needed to build internal corporate networks and websites. Eventually TopTier started licensing its software to such industry giants as SAP, Baan and Microsoft, leading Agassi to move his company from Tel-Aviv to Silicon Valley in 1992. Nine years after its founding, Agassi sold Top Tier Software to SAP for $400 million (Roth, 2009). When Agassi decided to accept the offer of joining SAP's 8 person executive leadership board and acting as CEO of an SAP subsidiary called SAP Portals, many industry insiders were surprised. Typically "after selling a brainchild, a computer-age entrepreneur would leave an established company in pursuit of the next exciting opportunity" (Neumann, 2003). Agassi seemed to have the big picture in mind however, noticing that chief technology officers were not gambling on big ideas from small new software companies, regardless of how promising their software may be. The industry wanted reliable solutions from big companies that would be stable over many years. Agassi recognized that SAP provided an environment where his ideas about computing could have the greatest impact on the market (Neumann, 2003). In an interview for Network World, Agassi describes his highly successful approach to software development as " 'looking at the world from customers' eyes and then trying to understand where complexity is and then designing it out - that's been the goal of my programming' " (As cited in Bednarz, 2003). This user centered approach, aiming for the most simple and elegant solution epitomises Agassi's designerly way of approaching software design and engineering. It turns out that this way of approaching problem solving would be instrumental in later founding Better Place.

Agassi continued to work for SAP as CEO of SAP Markets and SAP Portals and in 2005 he was invited to join the World Economic Forum's Young Global Leaders (YGL), a network of powerful politicians and business people under 40, who are challenged to start shaping a better tomorrow. At the first annual YGL 4 day meeting in Zermatt, Switzerland, Agassi worked with the group devoted to environmental risk. It didn't take long for Agassi to zero in on the most pressing issue contributing to the world's environmental crisis: energy. The invited participants were tasked with making the world a better place by 2020, and the summit in Zermatt planted a seed in Agassi's head that would lead him to reconsider his entire career path.

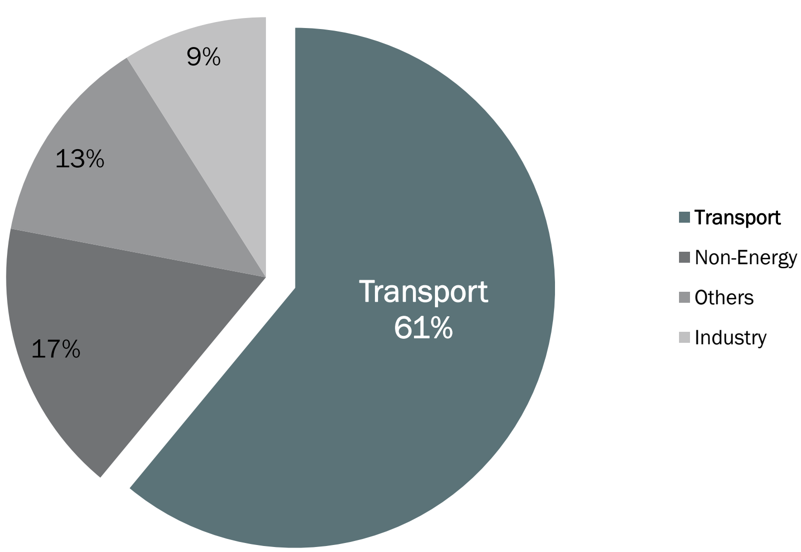
Returning to his day job at SAP, Agassi spent his nights home schooling himself in energy policy and the carbon economy, dining with energy experts and doing anything he could to bring the big picture of the problems with energy production and consumption into focus. Despite his new passion, Agassi's success at SAP was unmistakable and he was told that in 2007 he would be a successor to Henning Kagermann, SAP's CEO at that time. When Kagermann announced in 2007 that he would stay on as CEO for another two years, Agassi started to realize that he was running out of time to make the world "a better place" by 2020. As Agassi told Businessweek magazine in 2007, "I asked myself what are the passions that drive me forward? In the next ten years of my life, which would have more impact? And climate change is where I could make more impact" (Ham, 2007). With that in mind, 39 year old Agassi turned down an offer to lead the world's largest enterprise application software company with US $8.5 billion in annual revenues and left SAP to make good on his pact with the YGL. "Once you have a mission", Agassi points out to Wired Magazine's Daniel Roth, "you can't go back to having a job" (Roth, 2009, p. 122).

Appendix 7: 2007 Global Energy Supply



(Adapted from IEA, 2009)

Appendix 8: 2007 Shares of World Oil Consumption



(Adapted from IEA, 2009)

Appendix 9: Details of the Fluence Z.E. Electric Motor

The motor varies between 54 and 70 kW of power with 226 Nm of torque and offers a top speed of 135 km/h. At 160kg, the motor is significantly lighter than its gasoline counterpart so the front suspension is set softer in the Fluence Z.E. (Renault, 2010). The electric motor is composed of 4 distinct units as illustrated below: the interconnection box, the charger, the 12 volt electronic power unit and the 400 volt motor. The charger converts the incoming 230v current into the required 400v current, the interconnection box then transmits the current into the battery during charging and from the battery to the motor during driving, the electric power unit/converter powers the audio system and the lights, and the engine/reducer delivers power and torque to the axel.

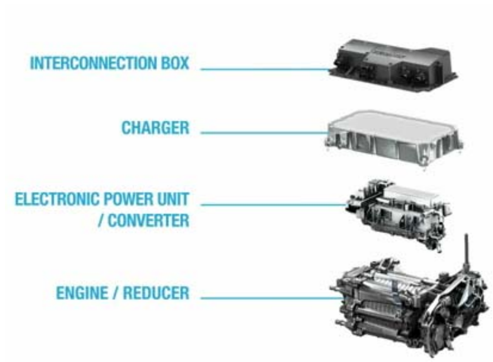


Figure 36: Details of the Fluence Z.E. Electric Motor (Screen capture from Renault, 2011a)

Appendix 10: Storyboard of the Swap Station Use Scenario

1) AutOS notifies the user of the closest swap station when the battery charge is low.

2) The driver engages the car on a track similar to one at an automatic car wash.

3) A mechanism under the car dislocates the depleted battery which is lowered out of the vehicle on a hydraulic platform.

4) A rotating tray replaces the depleted battery on the platform with a recharged one.

5) The hydraulic platform raises the charged battery into the car where it is secured into place.

6) The driver can then drive away without the need to leave the car for either the swapping procedure or for payment.

(Images are screen captures fromRenault, 2011b)

Appendix 11: The First Six Faces of Sustainability for Interface

Eliminate Waste: The issue is that industrial processes generate huge amounts of waste that cannot be returned to nature or reintegrated into the industrial stream of materials. As viewed by Interface, all waste is the result of inefficiencies in its processes that have negative environmental and economic consequences and ultimately diminish customer value. By first reducing and then by eliminating the concept of waste altogether, Interface plans to turn negative consequences for the environment, their bottom line and their customers into positive consequences. Interface defines waste as any measurable input that goes into their product that does not produce value to their customers, including all raw materials consumed in the production of their carpets.

Benign Emissions: Probably surprising to most people is that industry in general produces more harmful emissions than solid waste. These include "small concentrations of poisons, persistent man-made chemicals, and greenhouse gases" (Interface Inc., 2007). Interface is hoping to set an industry benchmark by completely eliminating smokestacks, effluent pipes or harmful waste in all of its factories.

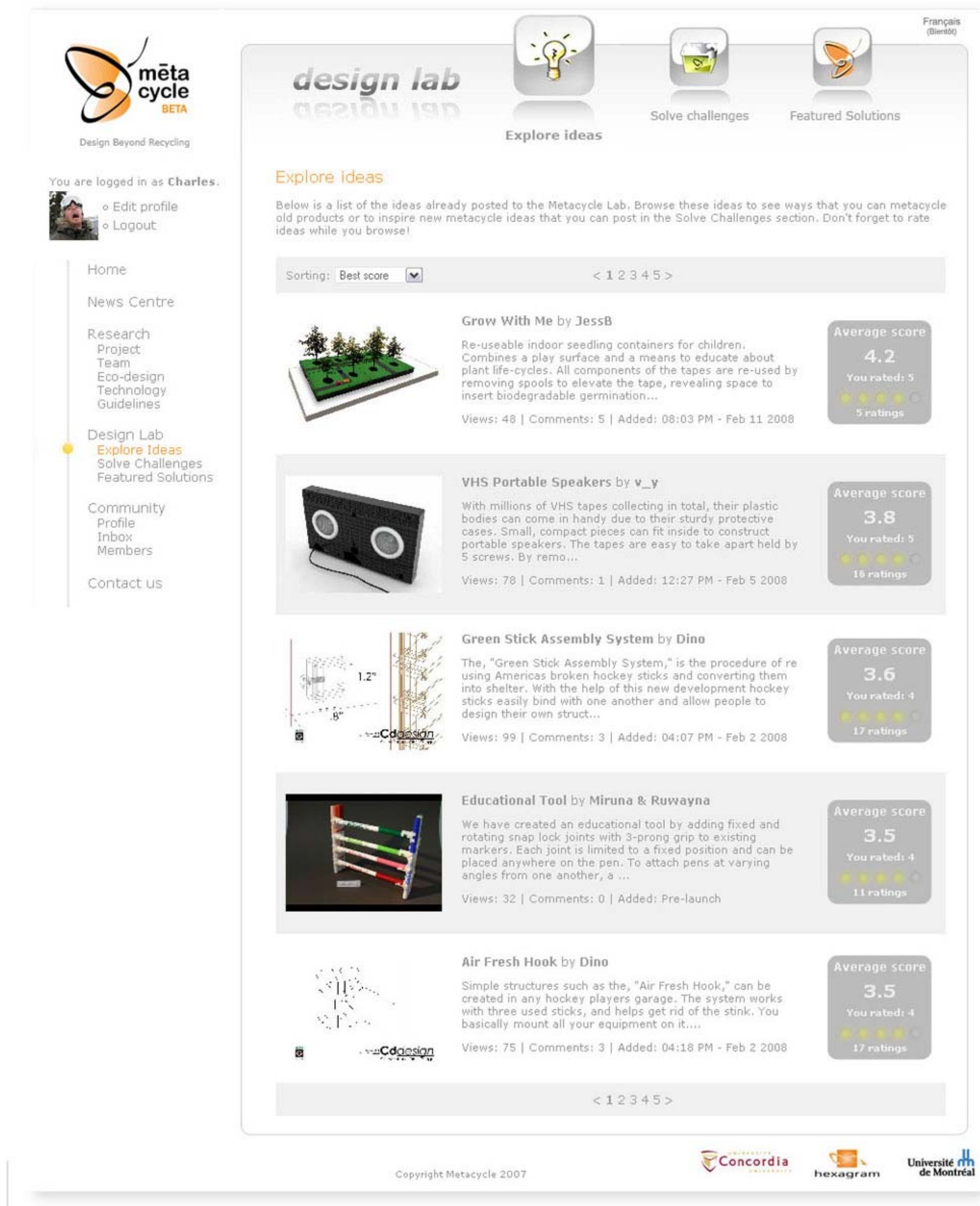
Renewable Energy: The quest for a complete switch to renewable energy is ground zero in the transition to a sustainable society. Life cycle analysis studies show that energy use is commonly the greatest contributor to environmental impacts associated with any given product or process. The combustion of non-renewable fossil fuels such as oil, coal and natural gas is the main cause of climate change. Electricity production alone is responsible for one third of all of America's global warming pollution and when all of the health and environmental costs of burning coal for electricity are factored into the equation, the true cost is 50% higher than the market cost (Solomon & Heintzman, 2005).

Closing the Loop: To close the loop in its manufacturing, Interface has made the commitment to make only products that can stay in either biological nutrient cycles, or technical nutrient cycles. Biological nutrient cycles contain non contaminated organic materials that can be returned to their natural systems and technical nutrients are synthetic materials that can be recycled to become valuable raw materials for industry. Interface also acknowledges that all recycling must also be done with renewable energy because a fossil fuel-based recycling process may in fact burn more fossil fuels than extracting virgin raw materials (Anderson, 2004a).

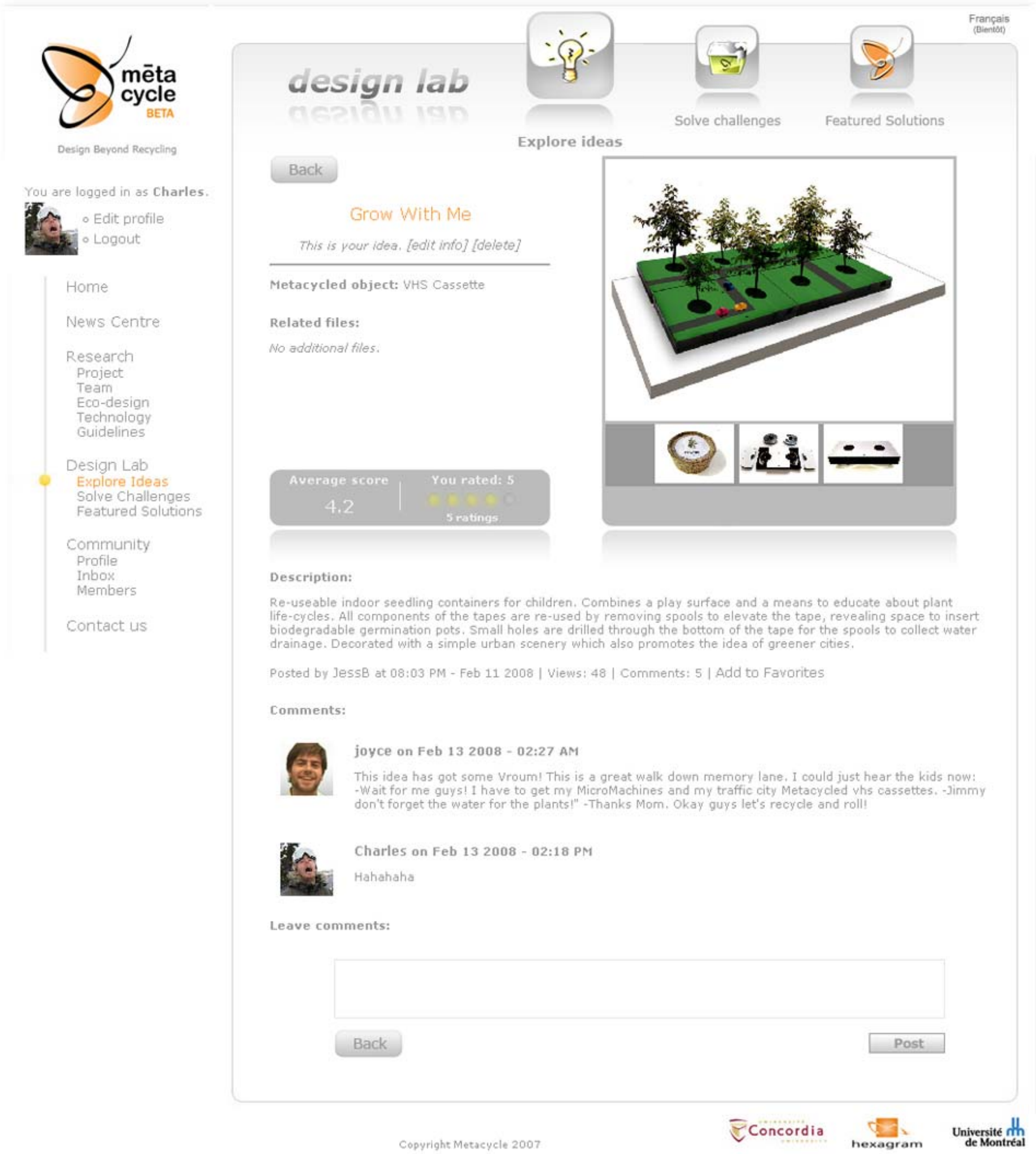
Resource Efficient Transportation: Transportation for Interface includes moving people, products, information and resources (Interface Inc., 2007). Anderson explains how the company takes measures whenever it can, such as using video conferencing, driving efficient vehicles, planning logistics efficiently, and even building factories close to markets but that ultimately, the company is dependent on the transportation industry to innovate its unsustainable, fossil fuel based model. To do what it can though, Interface has established a Transportation Working Group comprised of members from many international Interface business units. This working group is calculating the company wide transportation footprint, establishing a baseline year, keeping metrics to monitor performance and sharing best practices between business units (Interface Inc., 2007). Interface is also a partner of the U.S. Environmental Protection agency's Safeway Transport partnership and has won a Safeway Excellence Award for its efficient logistics developed with its consulting logistics firm Meridian IQ. Through the carbon offsetting program Trees for Travel, Interface plants a tree for every 1,500 miles that an employee flies for business related purposes which has already amounted to over 62,000 trees. Furthermore, Interface has an employee driven program called Cool Commute to create more efficient employee commuting and a program called Cool Fuel that offsets all carbon-dioxide emissions associated with business related auto travel.

Sensitizing Stakeholders: Sensitizing Stakeholders is grounded in the belief that everything is interconnected. Anderson called all relevant parties who understood and needed to understand 'stakeholders' and felt that all stakeholders including employees, customers, suppliers, communities, and even competitors, needed to understand that "environmental sustainability is not only the right thing to do, but the smart thing to do" (Interface Inc., 2007). Because of the world's interconnectedness, by investing in community and education, and by creating closer relationships with customers and suppliers, Interface was effectively creating closer bonds among its employees, and building a stronger more connected company.

Appendix 12: Screen Shot of Metacycle Design Lab

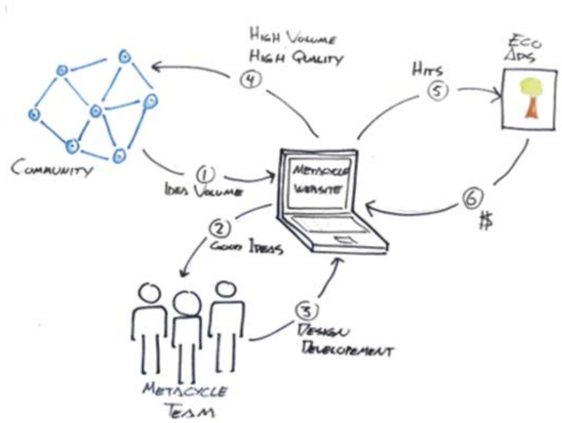


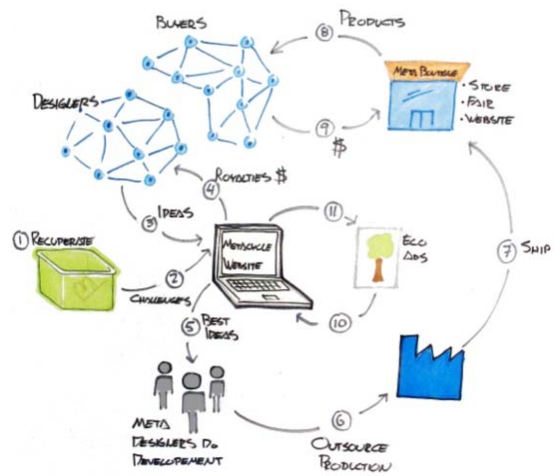
Appendix 13: Screen Shot 2 of Metacycle Design Lab

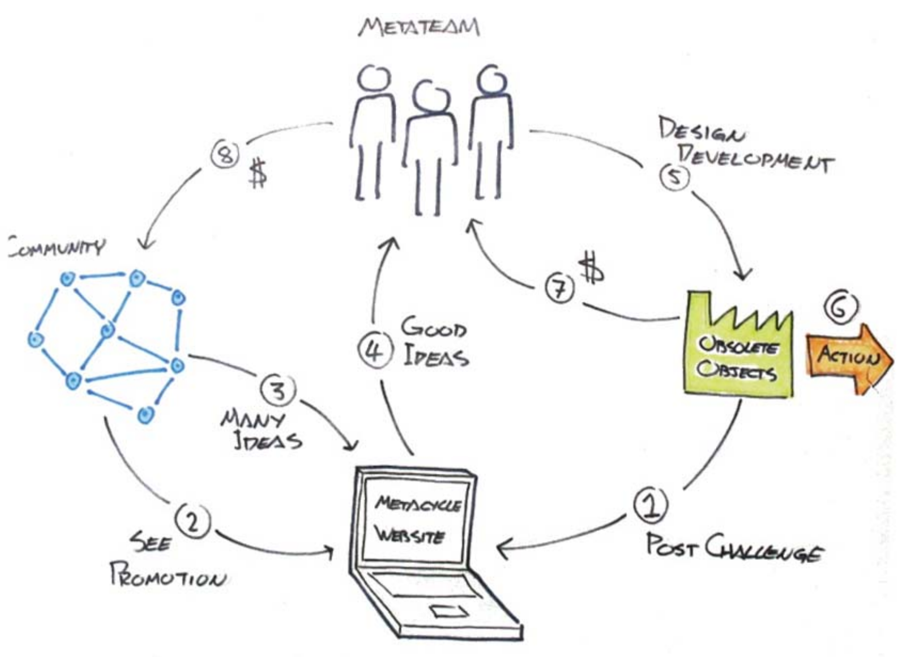


Appendix 14: Screen Shot 3 of Metacycle Design Lab

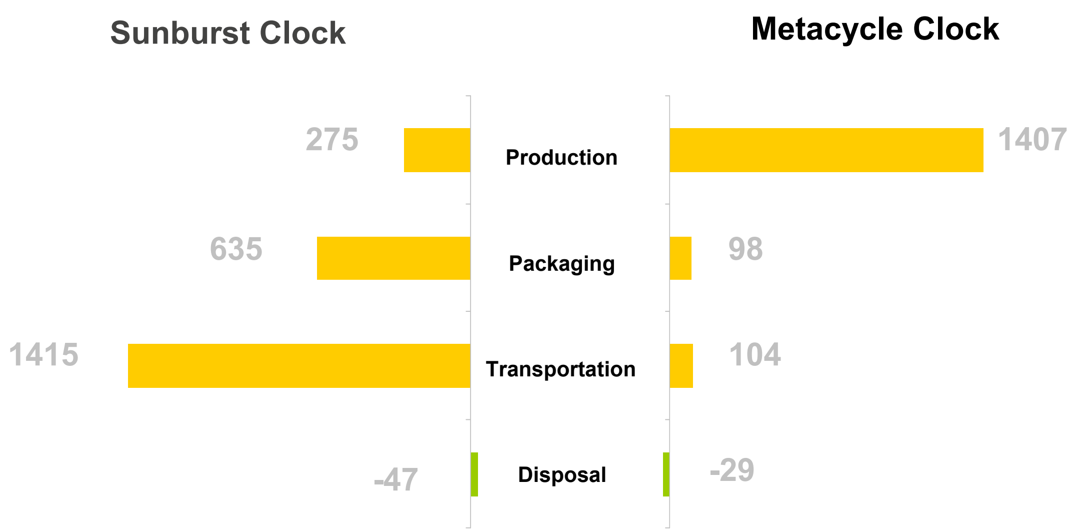
Appendix 15: Iterations of the Metacycle Business Model



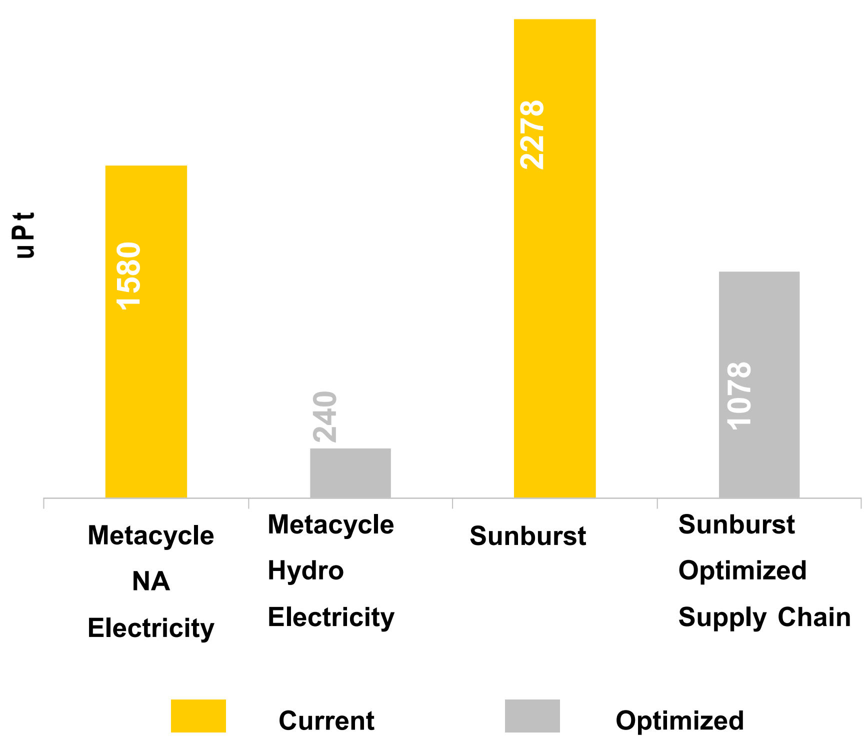




Appendix 16: Comparative LCA of Two Clocks in the Metacycle Model



Comparative LCA results for each life cycle stage (Colby et al., 2009)



Comparative LCA results of optimized scenarios (Colby et al., 2009)